UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH
Computational Biology and Complex Systems Research Group
CMCiB Comparative Medicine & Bioimage Centre of Catalonia
IGTP Germans Trias i Pujol Research Institute

Daily report 22-04-2020

Analysis and prediction of COVID-19 for EU-EFTA-UK and other countries

Contact: clara.prats@upc.edu

With the financial support of: MINISTERIO DE CIENCIA E INNOVACIÓN "la Caixa"

Foreword

The present report aims to provide a comprehensive picture of the **pandemic situation of COVID-19** in the EU countries, and to be able to foresee the situation in the next coming days.

We employ an **empirical model**, verified with the evolution of the number of confirmed cases in previous countries where the epidemic is close to conclude, including all provinces of China. The model does not pretend to interpret the causes of the evolution of the cases but to permit the **evaluation of the quality of control measures made in each state** and a **short-term prediction of trends**. Note, however, that the effects of the measures' control that start on a given day are not observed until approximately 7-10 days later.

The model and predictions are based on two parameters that are daily fitted to available data:

- ✓ *a*: the velocity at which spreading specific rate slows down; the higher the value, the better the control.
- ✓ *K*: the final number of expected cumulated cases, which cannot be evaluated at the initial stages because growth is still exponential.

We show an individual report with 8 graphs and a table with the **short-term predictions** for different countries and regions. We are adjusting the model to **countries and regions** with at least 4 days with more than 100 confirmed cases and a current load over 200 cases. The **predicted period** of a country depends on the number of datapoints over this 100 cases threshold, and is of 5 days for those that have reported more than 100 cumulated cases for 10 consecutive days or more. For short-term predictions, we assign higher weight to last 3 points in the fittings, so that changes are rapidly captured by the model. The whole methodology employed in the inform is explained in the last pages of this document.

In addition to the individual reports, the reader will find an initial dashboard with a brief analysis of the situation in EU-EFTA-UK countries, some summary figures and tables as well as **long-term predictions** for some of them, when possible. These long-term predictions are evaluated without different weights to data-points. We also discuss a specific issue every day.

Martí Català
Pere-Joan Cardona, PhD
Comparative Medicine and Bioimage Centre of Catalonia; Institute for Health Science Research Germans Trias i Pujol

Clara Prats, PhD
Sergio Alonso, PhD
Enric Álvarez, PhD
Miquel Marchena
Daniel López, PhD
Computational Biology and Complex Systems; Universitat Politècnica de Catalunya - BarcelonaTech

With the collaboration of: Guillem Álvarez, Oriol Bertomeu, Laura Dot, Lavínia Hriscu, Helena Kirchner, Daniel Molinuevo, Pablo Palacios, Sergi Pradas, David Rovira, Xavier Simó, Tomás Urdiales

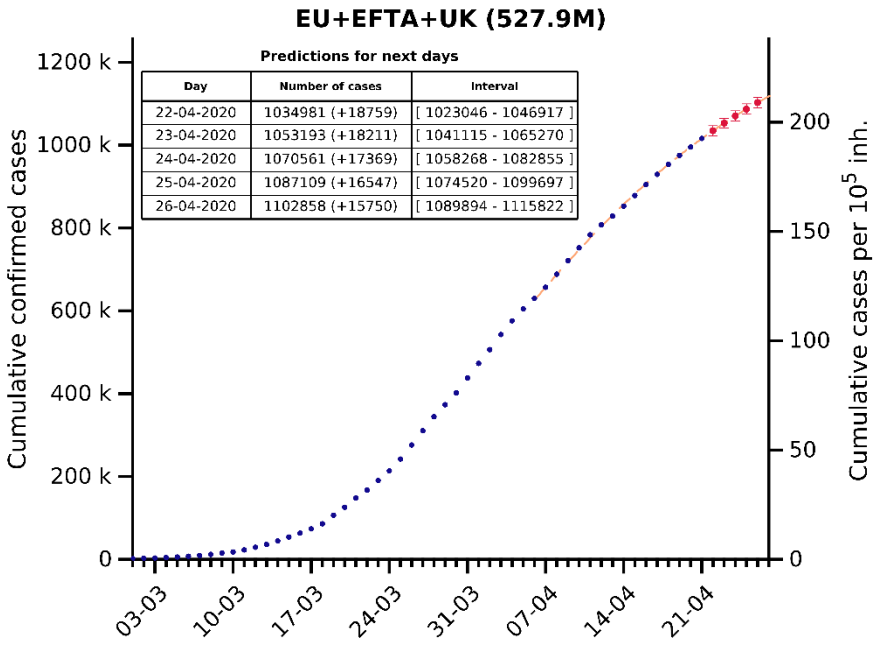
PJC and MC received funding from "la Caixa" Foundation (ID 100010434), under agreement LCF/PR/GN17/50300003; CP, DL, SA, MC, received funding from Ministerio de Ciencia, Innovación y Universidades and FEDER, with the project PGC2018-095456-B-I00;

Disclaimer: These reports have been written by declared authors, who fully assume their content. They are submitted daily to the European Commission, but this body does not necessarily share their analyses, discussions and conclusions.

(0) Executive summary – Dashboard

Global EU+EFTA+UK trends and needs

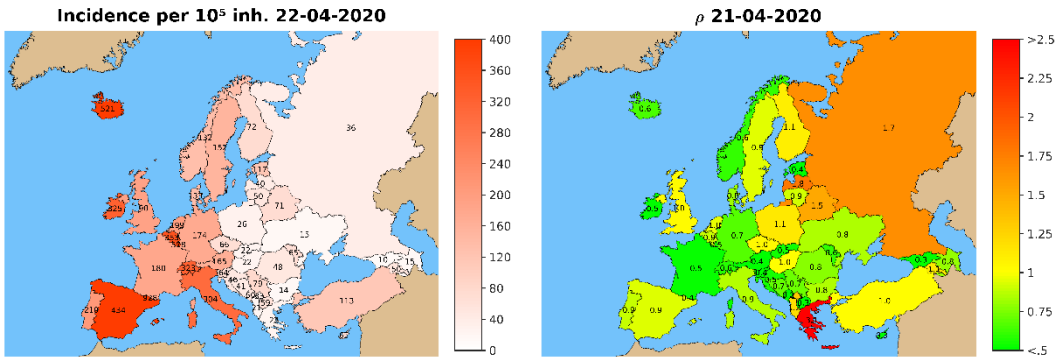
The forecast for the set of EU+EFTA+UK countries indicates that the **number of new cases per day is decreasing, although the observed incipient oscillation will probably modulate its shape**. Globally, we are closer to control, which is undeniably positive. However, if we look at the relative incidence, it is at the level of 195 cases per 100,000 inhabitants, which is high. Indeed, it is in the range of attack rate in UK, one of the countries with a significant impact of the epidemic. This average incidence can be understood by looking at most populated countries, with a higher contribution to such average. Looking at the perspective of reported cases and assuming that they are a realistic picture of the situation, **we can divide the countries into three groups**: (i) those with more than 10% of EU+EFTA+UK cases, which are Spain (20.1%), Italy (18.1%), Germany (14.3%), United Kingdom (12.7%) and France (11.5%); (ii) those with 1 to 10% of total cases, which are Belgium (4.0%), Netherlands (3.4%), Switzerland (2.8%), Portugal (2.1%), Ireland (1.6%), Sweden (1.5%), Austria (1.5%) and Poland (1%); (iii) the rest of the countries, which have a percentage in the number of cases less than 1% of the total. There are 16 states with less than 100 new cases daily. It is clear that the top 5 countries are those that determine the global dynamics and mask the contribution of countries with fewer cases.



In the Analysis section, as a continuation of yesterday's assessment, we discuss how to **estimate real number of recovered cases and 14-day attack rate**, as well as the resulting **implications on risk evaluation**.

Trends for specific countries

Focusing on active cases, highest 14-day reported cases corresponds to **UK** (73,802 cases) followed by **Spain** (63,688), **Italy** (48,371), **Germany** (42,466) and **France** (39,157). In relative terms, highest reported 14-day attack rate is found in **Ireland** (218.6/10^5 inh.), **Belgium** (165.2), **Spain** (137.4), **Luxembourg** (112.5) and **UK** (111.1). Nevertheless, reported cases are biased by diagnostic rate. As discussed in the Analysis section, the number of real cases the last 14 days can be roughly estimated. If done, highest value corresponds to **UK** as well (1,200,000), but then followed by **France** (850,000), **Spain** (740,000), **Italy** (700,000) and **Belgium** (420,000). If given by 10^5 inhabitants, the estimated 14-day attack rate rank is led by **Belgium** (3,600) and followed by **Ireland** (2,000), **UK** (1,700), **Spain** (1,600) and **Sweden** (1,500).



Situation and trends per country

Table of current situation in EU countries, according to data published by ECDC on April 15th. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables.

	Reported data						Indexes		
Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	Mean ρ[1]	EPG[2]	EPG2[2]
Spain	204,178	440.5	21,282	45.9	63,668	137.4	1.07	146.9	157.1
Italy	183,957	309.5	24,648	41.5	48,371	81.4	0.94	76.9	72.6
Germany	145,694	177.9	4,879	6.0	42,466	51.8	0.86	44.5	38.3
United Kingdom	129,044	194.2	17,337	26.1	73,802	111.1	1.10	122.0	134.1
France	117,324	181.3	20,796	32.1	39,157	60.5	0.47	28.1	13.1
Belgium	40,956	360.6	5,998	52.8	18,762	165.2	1.02	168.6	172.1
Netherlands	34,134	200.9	3,916	23.1	14,554	85.7	1.08	92.9	100.7
Switzerland	27,981	326.5	1,186	13.8	5,817	67.9	0.80	54.2	43.2
Portugal	21,379	206.1	762	7.3	8,937	86.2	1.02	87.5	88.8
Ireland	16,040	339.4	730	15.4	10,331	218.6	0.61	134.3	82.5
Sweden	15,322	155.7	1,765	17.9	7,629	77.5	1.15	89.2	102.5
Austria	14,833	170.3	463	5.3	2,193	25.2	0.48	12.2	5.9
Poland	9,856	25.8	401	1.0	5,008	13.1	1.36	17.9	24.3
Romania	9,242	46.7	483	2.4	4,825	24.4	0.96	23.5	22.6
Denmark	7,695	134.7	370	6.5	2,624	45.9	0.89	40.7	36.1
Norway	7,166	133.5	163	3.0	1,303	24.3	0.99	23.9	23.6
Czech Republic	7,041	66.4	201	1.9	2,024	19.1	1.23	23.4	28.8
Finland	4,014	72.9	141	2.6	1,706	31.0	1.38	42.9	59.3
Luxembourg	3,618	628.1	78	13.5	648	112.5	1.42	159.2	225.3
Greece	2,401	21.5	121	1.1	569	5.1	1.31	6.7	8.7
Hungary	2,168	22.2	225	2.3	1,273	13.1	1.22	16.0	19.6
Croatia	1,908	45.3	48	1.1	626	14.9	0.49	7.4	3.6
Iceland	1,778	488.1	10	2.7	192	52.7	0.80	42.3	33.9
Estonia	1,552	118.3	43	3.3	403	30.7	0.86	26.3	22.6
Lithuania	1,370	47.1	38	1.3	490	16.9	5.05	85.1	429.8
Slovenia	1,340	64.5	77	3.7	285	13.7	1.02	14.0	14.4
Slovakia	1,199	22.0	14	0.3	618	11.4	1.09	12.4	13.5
Bulgaria	975	13.7	45	0.6	398	5.6	1.40	7.8	11.0
Cyprus	784	67.0	17	1.5	290	24.8	0.39	9.7	3.8
Latvia	748	38.0	9	0.5	200	10.1	2.51	25.5	63.9
Malta	443	103.3	3	0.7	150	35.0	ND	ND	ND
Liechtenstein	82	212.7	1	2.6	4	10.4	ND	ND	ND
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	500.0	500.0
	Best	Best	Best	Best	Best	Best	0.0	0.0	0.0

[1] Disclaimer: parameter ρ is very sensitive and experiments daily variations. Mean ρ is averaged per 3 consecutive days, but it can still vary the following days. [2] EPG stands for Effective Growth Potential. It is obtained by multiplying attack rate per 10^5 inhabitants of last 14 days (i.e. density of cases) by ρ (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). EPG2 is a similar index but attack rate of last 10 days is multiplied by ρ^2.

Highlights for countries with highest number of reported cases

- ✓ UK could be turning into a decreasing trend like Spain, Italy, Germany and France. Expected new cases for next days are at the range of 4,000 (UK), 3,800 (Spain), 2,300 (Italy), 1,600 (Germany) and 1,600 (France). Values are in accord to those reported yesterday, no drastic changes are detected.
- ✓ Spreading rates of these countries keep fluctuating around 1 except France, which shows an empirical ρ of 0.5 maybe related with under-reporting.

Time indicators by country

This table summarizes a few time indicators for each country: time since 50 cases were reported, time interval between an attack rate of $1/10^5$ inhabitants and an attack rate of $10/10^5$ inhabitants, and time interval between attack rates of 10 to 100 per 10^5 inhabitants (only for countries that have overtaken this threshold).

Countries	Days since the first 50 cases	Time interval between 1 and 10 cases / 10^5 inh. (days)	Time interval between 10 and 100 cases / 10^5 inh. (days)
Italy	60	11	16
France	54	10	20
Germany	54	12	17
Spain	53	7	12
United Kingdom	50	11	19
Norway	49	9	24
Switzerland	49	9	12
Netherlands	48	11	20
Sweden	48	10	28
Austria	47	10	14
Belgium	47	11	14
Greece	46	17	ND
Iceland	46	5	15
Denmark	44	4	30
Czech Republic	43	11	ND
Finland	42	12	ND
Portugal	42	9	15
Slovenia	42	6	ND
Ireland	41	8	18
Romania	41	12	ND
Estonia	40	5	30
Poland	40	9	ND
Bulgaria	38	12	ND
Luxembourg	38	6	7
Slovakia	38	14	ND
Croatia	37	12	ND
Latvia	36	12	ND
Cyprus	35	12	ND
Hungary	35	9	ND
Malta	34	8	34
Lithuania	33	9	ND
Liechtenstein	28	9	11

Analysis: Estimating real incidence in European countries (II).

In yesterday's report (21st April) we explained the methodology for estimating the real number of cases in each country, together with the Diagnosis Delay (DD) and the Diagnostic Rate (DR). Today's analysis exposes the **way to evaluate the recovered people and a more realistic EPG**, based on real incidence's estimation. The analysis is organized as follows. We first recall the calculations using Belgium as case study (1), which is one of the countries with a worrying situation. Then, we explain how to evaluate recovered cases and active cases. Finally (3), we show the results for all the countries that meet the criteria (>100 deaths at the moment of analysis), also updating EPG values with estimations.

1. Estimating real incidence, diagnostic rate and diagnosis delay in Belgium

a) Real number of cases 18 days ago

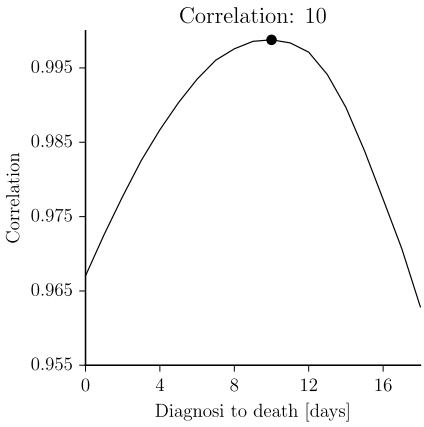
Assuming a lethality of 1% and a *Time to Death* (TtD) of 18 day (as discussed yesterday), the number of estimated cases on 3rd April (using data published 21st April) is:

$$estimated\ (3^{rd} April) = \frac{5{,}828}{0.01} = 582{,}800\ cases$$

According to reported data, on 3rd April Belgium accounted for 15,348 cases.

b) Diagnosis Delay

Correlation analysis between diagnosed cases and deaths allows for the estimation of *Diagnosis to Death* (DtD) time. This is found to be 10 days [8 – 12 days], as shown in figure. Given the equation $TtD = DD + DtD$, we can infer that DD ≈ 8 days [6 – 10 days].



c) Diagnosis Rate

Now, given the estimated interval for DD, we hypothesise that the estimated cases in point *a* (582,000) will be diagnosed DD days after the onset of the symptoms (DD ≈ 8 days [6 – 10 days]). Then, the *Diagnostic Rate* (DR) will be:

$$DR(t+8) = \frac{reported(t+8)}{estimated(t)} = \frac{26{,}667}{582{,}800} = 4{,}5\ \%$$

d) Current number of cases

Finally, the estimation of a DR allows for the assessment of current total cases that should have been diagnosed as follows:

$$estimated\ detectable(21^{st}\ April) = \frac{detected(t)}{DR} = \frac{39{,}983}{0.045} = 888{,}500\ cases$$

In fact, these are the cases that could have been diagnosed on 21st April but, assuming the estimated DD, they really correspond to 8 days ago (13th April). Nevertheless, if we are aiming to describe the situation in 21st April, this should be the total number of diagnosed cases.

2. Estimating recovered and active cases

If lethality is around 1%, percentage of recovered will be 99 %. We can assume an indicative value of around 20 days for the time from illness onset to discharge[1]. If we want to correctly analyse the whole picture of the

[1] Zhou, Fei, et al., 2020 "Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study." The Lancet.

country, we should obtain the recovered cases at the same moment at which estimated detectable were sick (i.e., with 8-day delay). Then, we can evaluate the number of recovered after 20 days as follows:

$$recovered(t) = 0.99 \cdot estimated(t - 20)$$

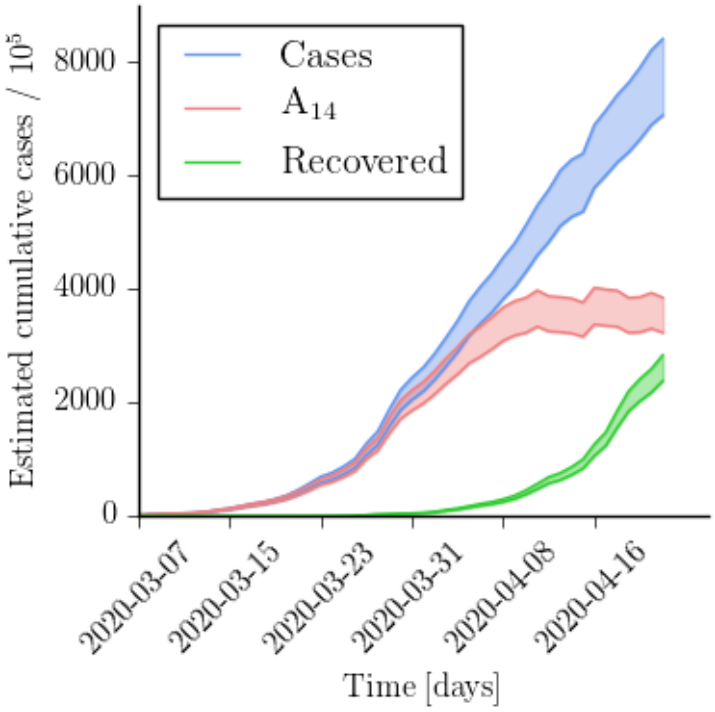
Using estimations for Belgium, we obtain:

$$recovered(t) = 0.99 \cdot estimated(t) = 0.99 \cdot \frac{deaths(t - 18)}{0.01} \approx 280{,}000$$

As discussed in previous reports, **a good indicator of infectious capacity of the country is the assessment of 14-day attack rate** (A_{14}). Given that we have an estimation of the real number of cases, we can also estimate a 14-day attack rate that is closer to real situation.

$$A_{14}(t) = \frac{estimated(t) - estimated(t - 14)}{Population} \cdot 100{,}000 = 3{,}600\ cases/10^5 inh$$

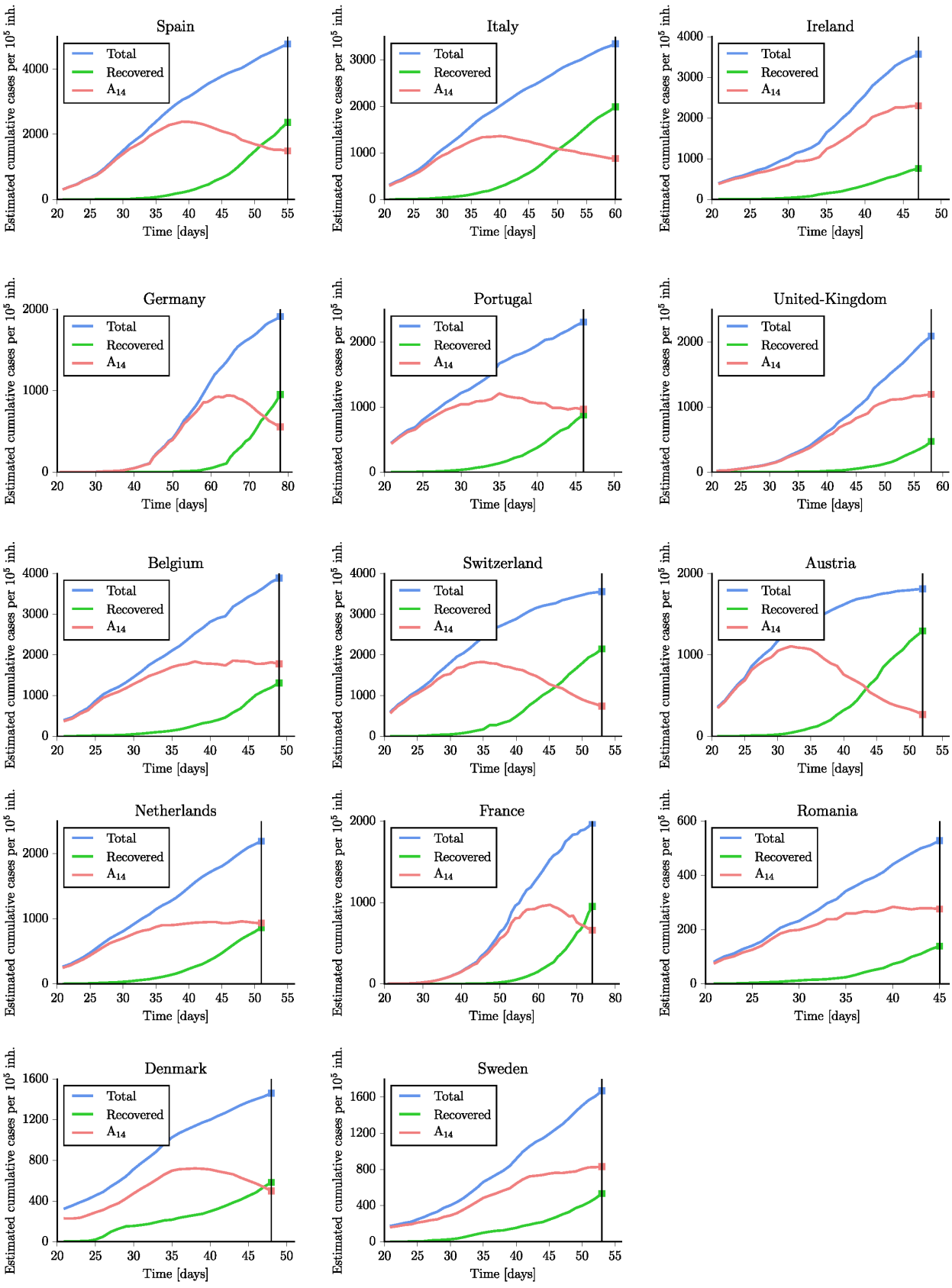
Next figure shows the evolution of estimated cases (blue), recovered (green) and 14-day attack rate (red) for Belgium, expressed by 10^5 inhabitants.



3. Results: estimations for European countries

a) Time evolution of estimated cases, recovered and 14-day attack rate

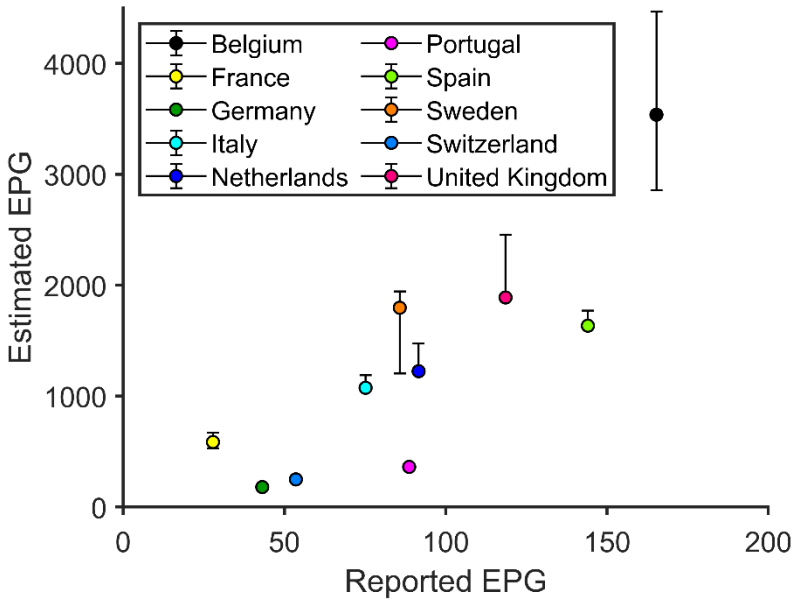
The next figure shows a panel of European countries with more than 100 reported deaths. For each of them, estimated cases (blue), estimated recovered (green) and estimated 14-day attack rate (red) per 10^5 inhabitants are shown. This analysis shows that Spain and Germany have overcome the estimated 14-day attack rate (A_{14}) peak, while Ireland and Netherlands are still showing an increase in this value. Belgium and UK show that the number of recovered would be lower than active cases, yet.



The following table shows the summary of estimations for all these countries. Italy, France and Spain show highest number of estimated recovered, but France and Italy are also among the three countries with highest estimated 14-day attack rate, together with UK.

Country	Estimated recovered			Estimated recovered /10^5 inh.			Active cases (last 14 days) I_{14}			Active cases (last 14 days) /10^5 inh. A_{14}			Reported EPG	Estimated EPG		
	Value	min	max	Value	min	max	Value	min	max	Value	min	max		Value	min	max
Austria	35000	34000	37000	390	370	410	8600	8200	9200	95	92	102	15	52	50	56
Belgium	280000	220000	360000	2400	1900	3100	420000	330000	530000	3600	2900	4600	169	3700	3000	4700
Czech Republic	11000	10000	13000	100	100	120	7200	6600	8500	67	62	79	24	83	77	98
Denmark	15000	15000	22000	270	260	380	15000	15000	22000	260	260	380	48	260	250	370
France	1100000	900000	1200000	1600	1500	1900	850000	750000	990000	1300	1200	1500	34	710	630	830
Germany	270000	250000	310000	330	290	370	180000	160000	200000	210	190	240	57	230	200	260
Greece	6900	6800	7500	66	66	72	2500	2500	2700	24	24	26	1	7	7	8
Hungary	14000	7000	14000	140	70	140	33000	16000	33000	340	170	340	17	450	220	450
Ireland	30000	17000	41000	610	330	820	97000	53000	131000	2000	1100	2600	149	1400	800	2000
Italy	1500000	1500000	1700000	2500	2500	2800	700000	700000	780000	1200	1200	1300	77	1100	1100	1200
Netherlands	170000	160000	200000	970	940	1190	190000	190000	240000	1100	1100	1400	90	1200	1200	1500
Poland	13000	11000	17000	33	29	44	28000	25000	38000	75	65	100	18	100	90	140
Portugal	30000	29000	34000	290	280	330	37000	36000	42000	360	350	410	96	390	380	440
Romania	13000	13000	17000	68	68	87	28000	28000	37000	150	150	190	26	150	150	200
Spain	1100000	1100000	1100000	2300	2300	2400	740000	740000	800000	1600	1600	1700	158	1800	1800	1900
Sweden	90000	59000	96000	890	580	960	150000	100000	160000	1500	1000	1600	99	2000	1300	2200
Norway	11000	10000	12000	200	190	220	3300	3100	3600	61	57	67	30	73	69	81
Switzerland	73000	69000	80000	840	790	930	28000	27000	31000	330	310	360	62	280	270	310
United Kingdom	410000	410000	540000	600	600	790	1200000	1200000	1600000	1700	1700	2300	113	1800	1800	2400

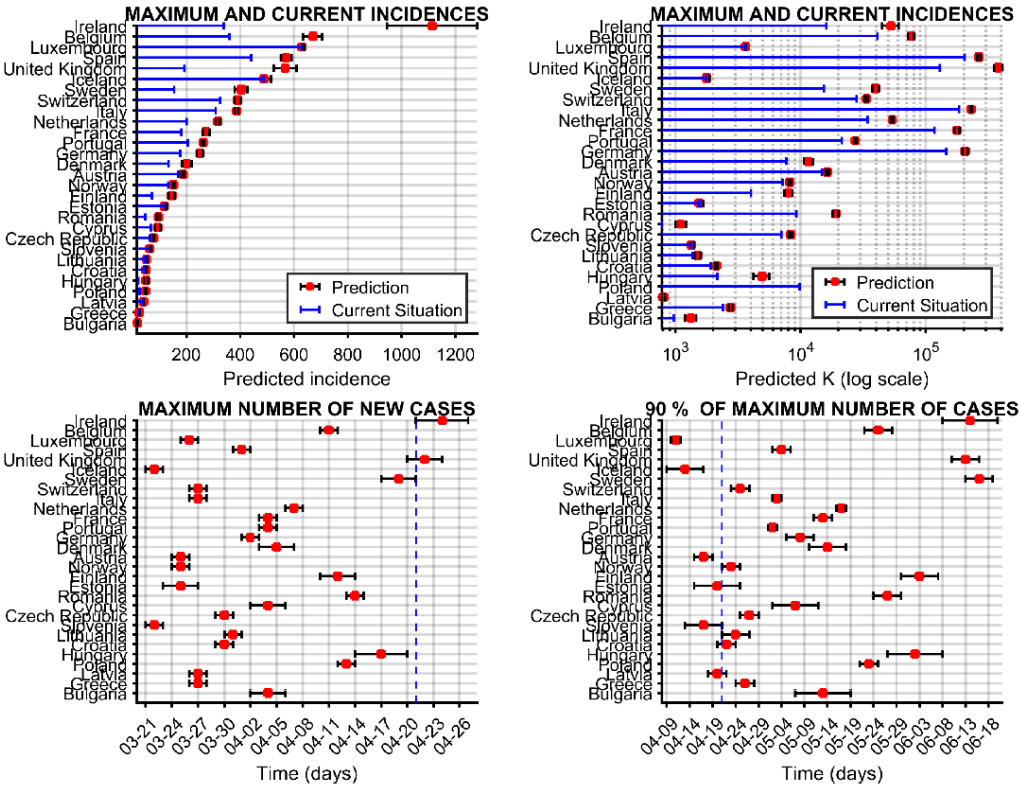
It is of special interest to look at the **EPG assessed with estimated 14-day attack rate, which changes the global picture for many countries**. As seen in the table and illustrated by the next figure, the EPG evaluated with reported data is not always in accord with the real estimated risk. Based on reported EPG, the worst situation would be for Belgium followed by Spain, Ireland, United Kingdom, Sweden and Portugal. If risk is evaluated with estimated EPG, highest value would still correspond to Belgium as well, but followed by Sweden, United Kingdom, Spain, Ireland, Netherlands and Italy. Countries with similar reported EPG like Portugal (96) and Netherlands (90) correspond to drastically different situations when we look at estimated EPG (1200 Netherlands vs 390 Portugal).



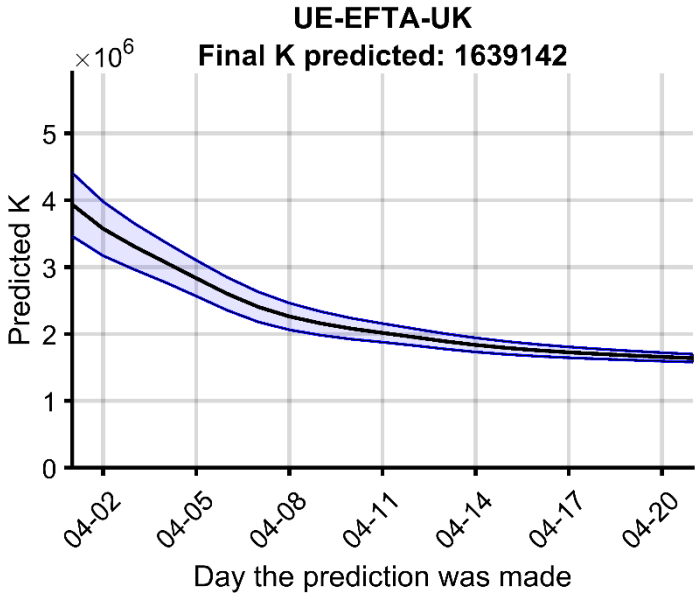
Long-term predictions

Long-term predictions, evaluated with the **whole historical series** and without weighting last 3 points. Up-left: Predictions of maximum incidences per country (total final expected attack rate per 10^5 inh.). Up-right: Predictions of maximum absolute number of cases per country (K, in log scale). Blue lines indicate current situation. Bottom-left: Time in which peak in new cases was achieved / will be achieved. Bottom-right: Time at which 90 % of K was achieved / will be achieved. Blue dotted line indicates current date. See details in Report from 11th April 2020.

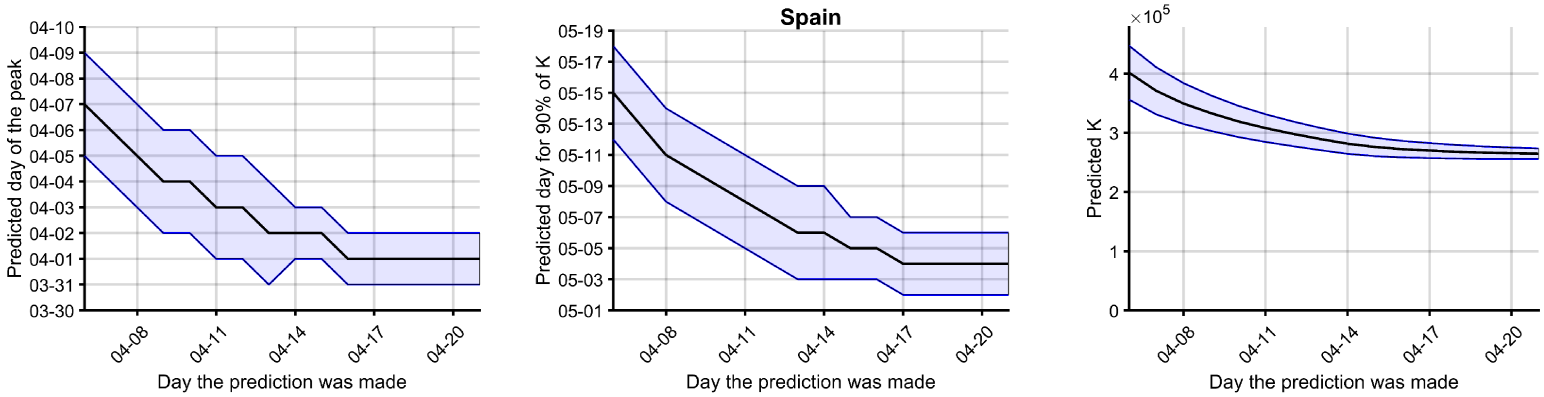
UE-EFTA-UK countries

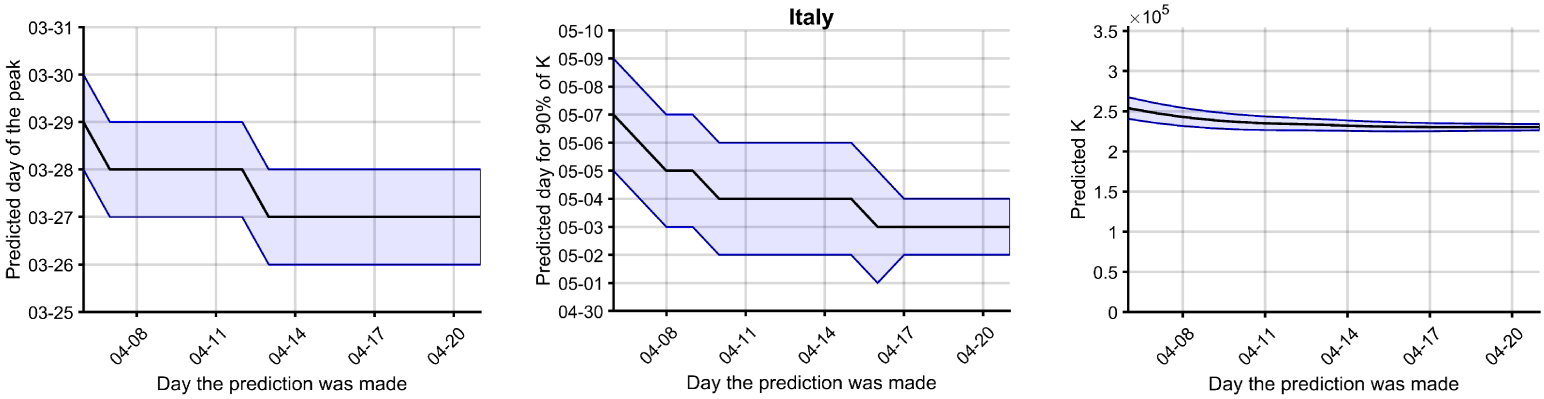


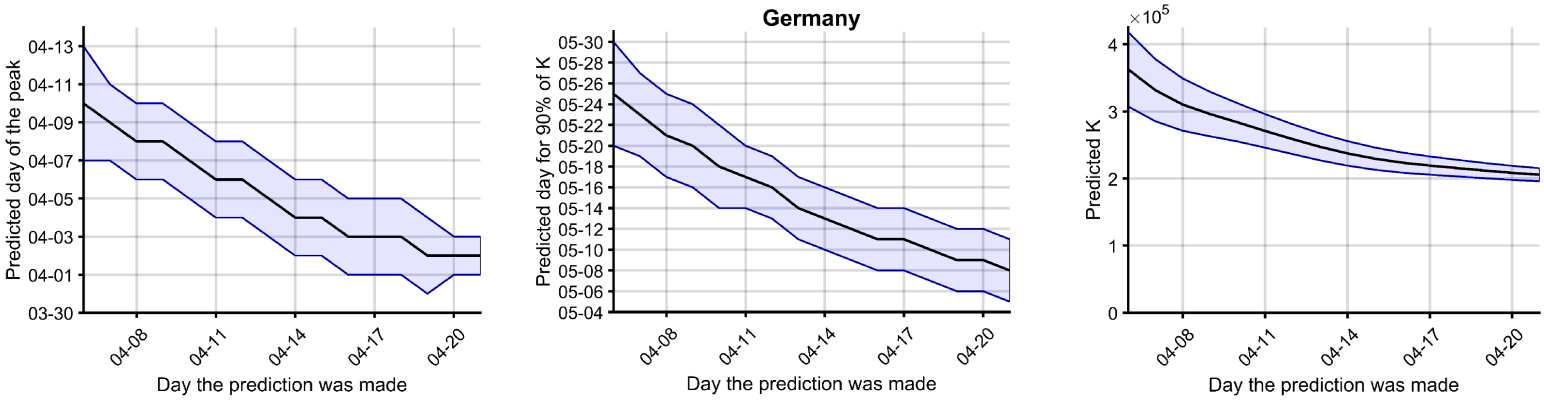
Final expected K for UE+EFTA+UK. Evolution of predicted K with time, where convergence to best estimate is seen. Last prediction is numerically shown in title.

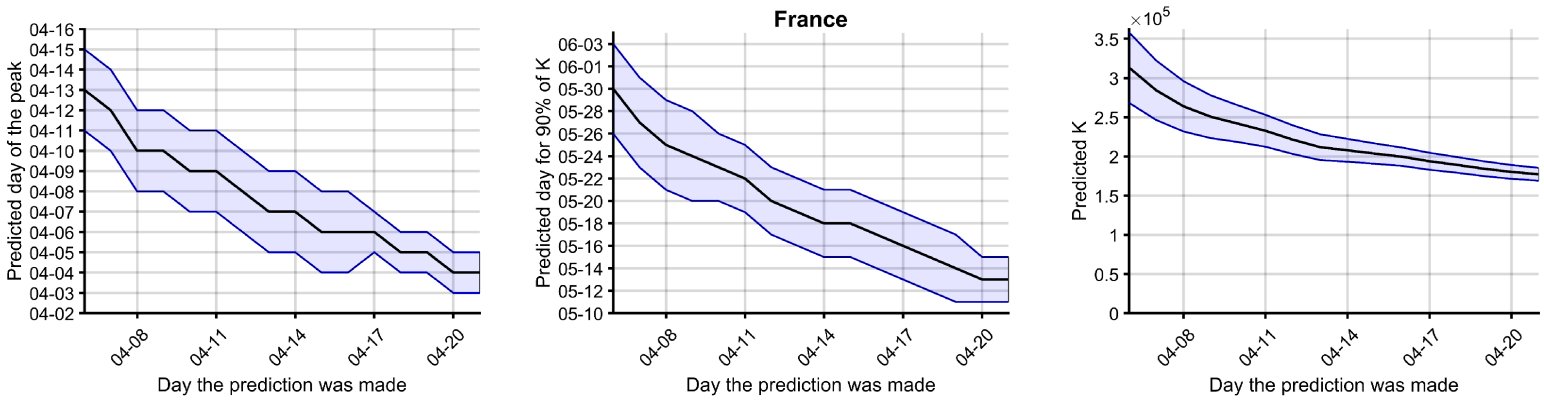


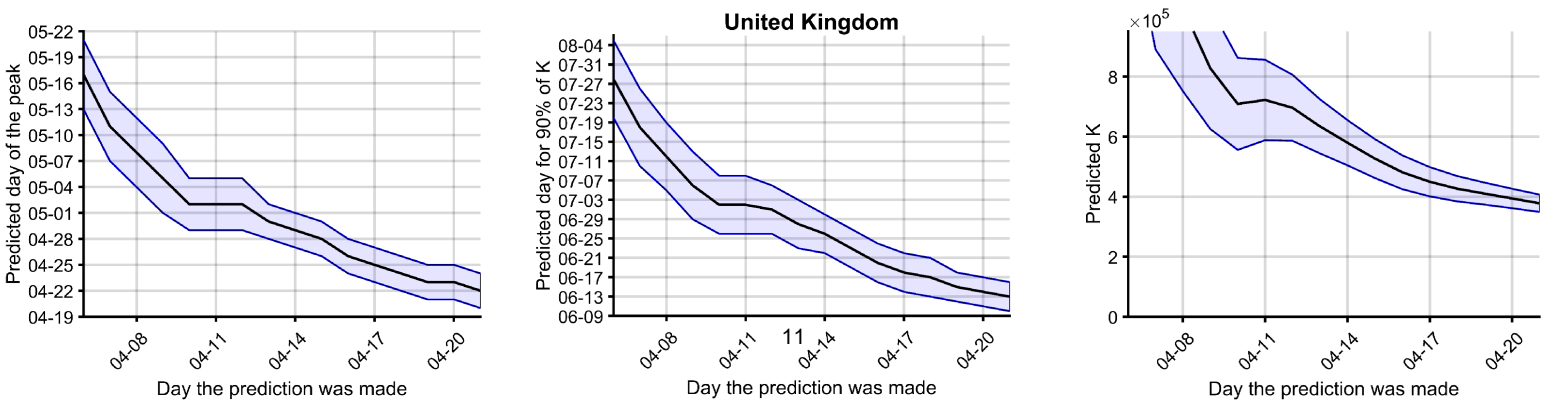
2020-04-21


Spain
Predicted day of the peak
Predicted day for 90% of K
Predicted K
×10^5
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

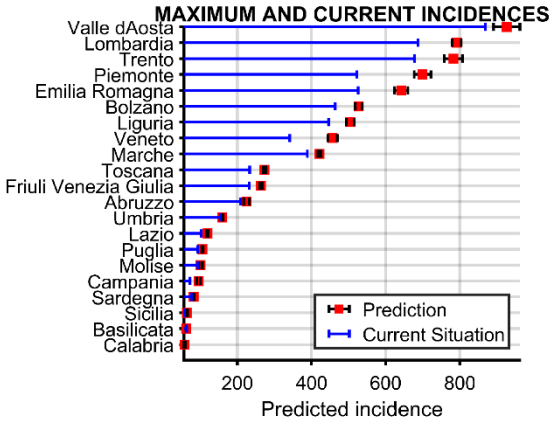

Italy
Predicted day of the peak
Predicted day for 90% of K
Predicted K
×10^5
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

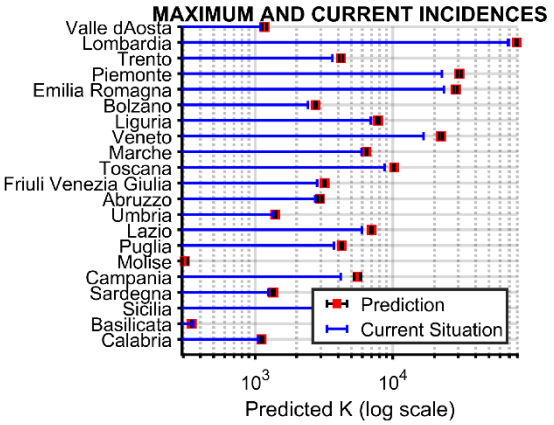

Germany
Predicted day of the peak
Predicted day for 90% of K
Predicted K
×10^5
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

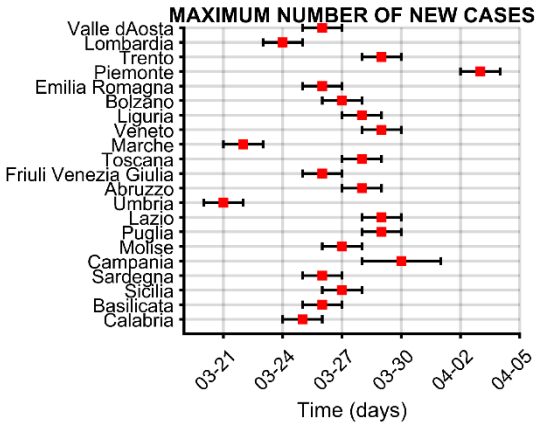

France
Predicted day of the peak
Predicted day for 90% of K
Predicted K
×10^5
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

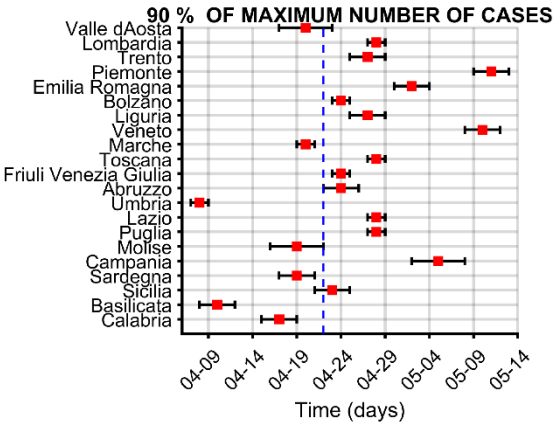

United Kingdom
Predicted day of the peak
Predicted day for 90% of K
Predicted K
×10^5
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

Italian regions

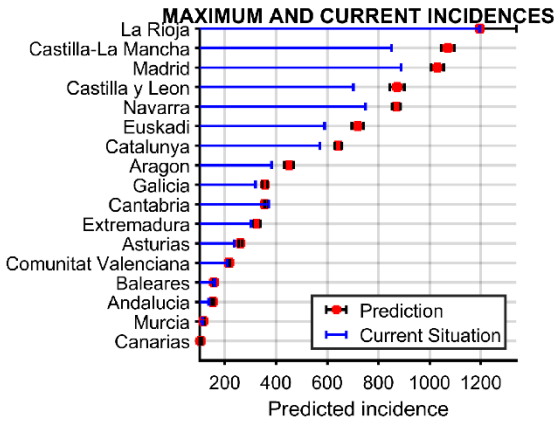


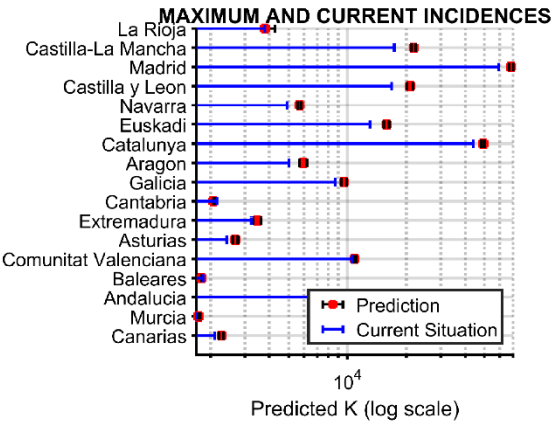


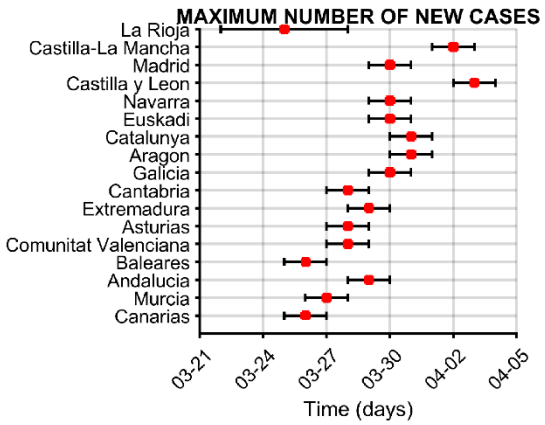


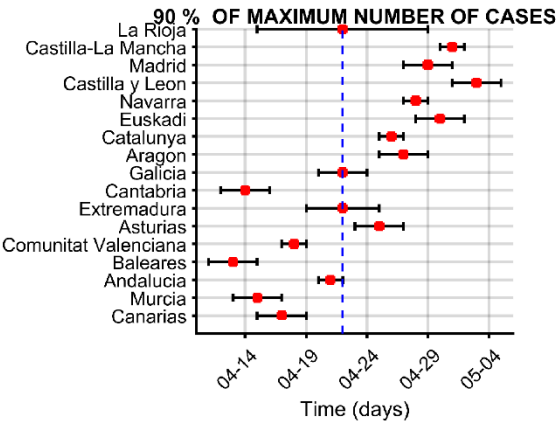


Spanish regions

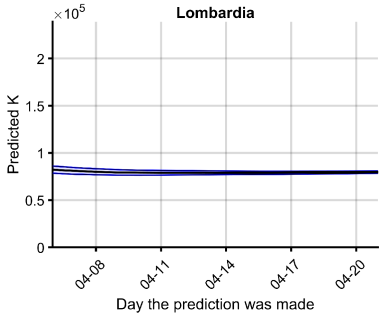


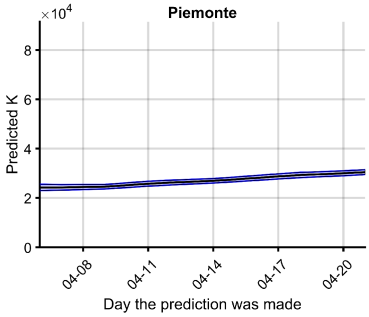


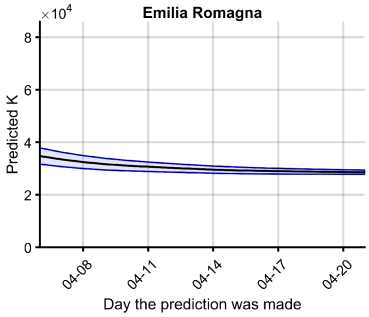


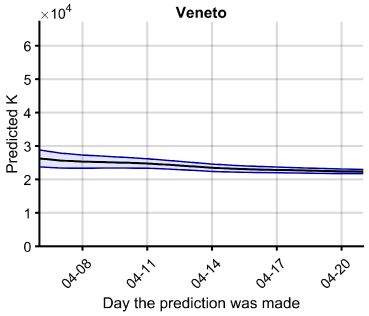


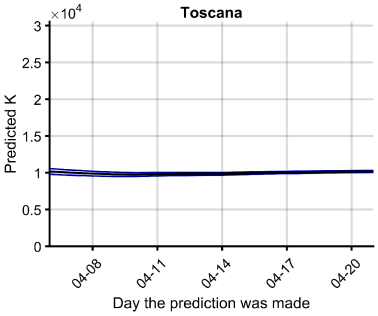
2020-04-22

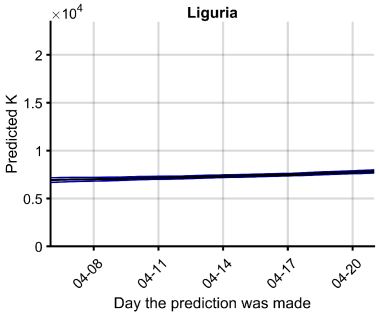

Lombardia
×10^5
Predicted K
Day the prediction was made

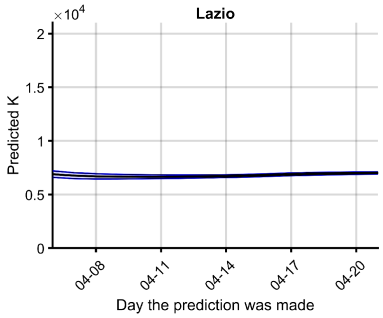

Piemonte
×10^4
Predicted K
Day the prediction was made

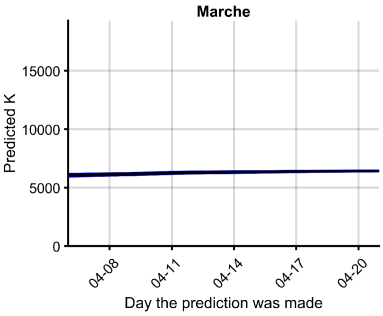

Emilia Romagna
×10^4
Predicted K
Day the prediction was made

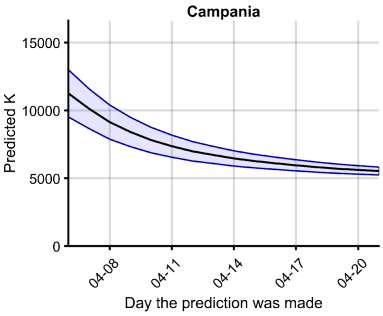

Veneto
×10^4
Predicted K
Day the prediction was made

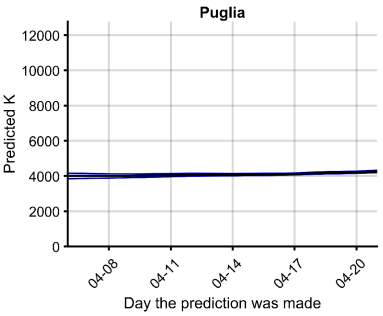

Toscana
×10^4
Predicted K
Day the prediction was made

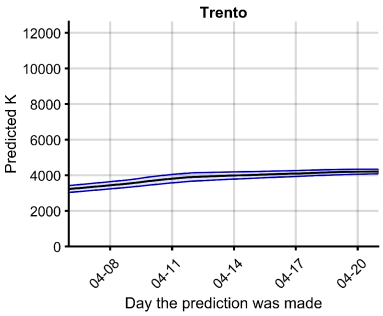

Liguria
×10^4
Predicted K
Day the prediction was made

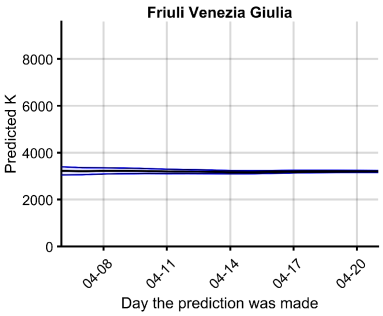

Lazio
×10^4
Predicted K
Day the prediction was made

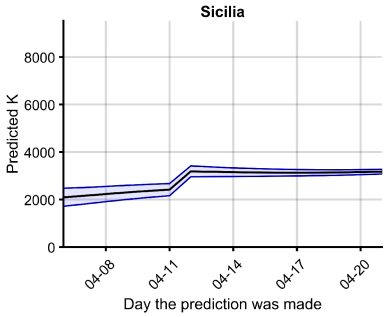

Marche
Predicted K
Day the prediction was made

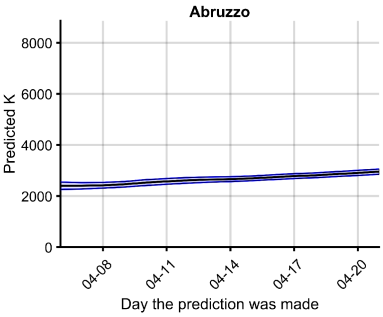

Campania
Predicted K
Day the prediction was made

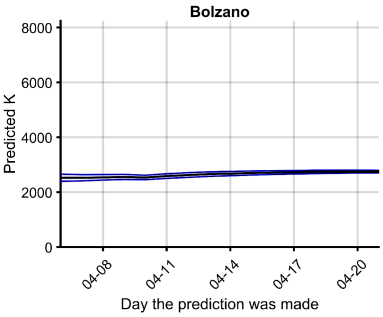

Puglia
Predicted K
Day the prediction was made

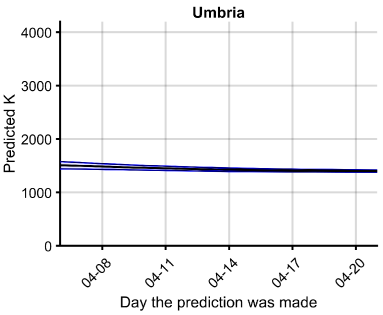

Trento
Predicted K
Day the prediction was made

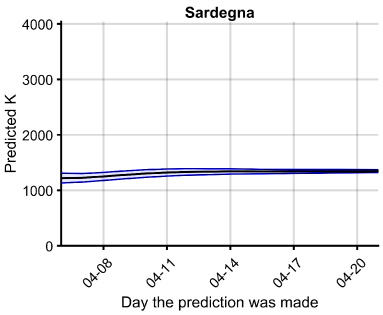

Friuli Venezia Giulia
Predicted K
Day the prediction was made

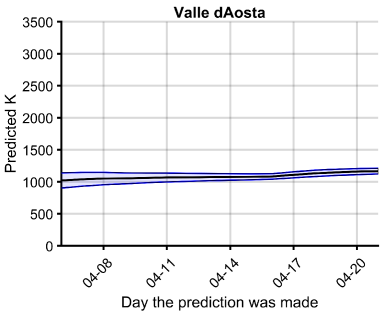

Sicilia
Predicted K
Day the prediction was made

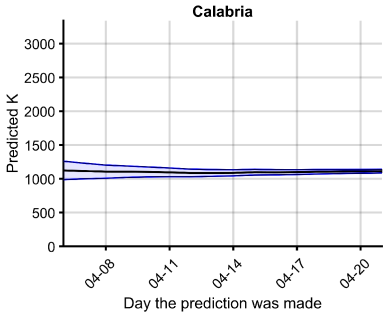

Abruzzo
Predicted K
Day the prediction was made

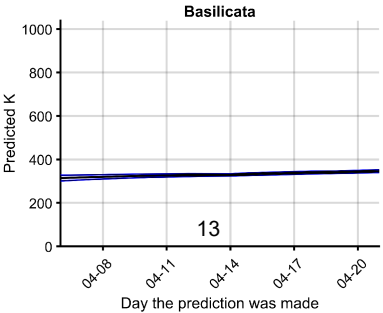

Bolzano
Predicted K
Day the prediction was made

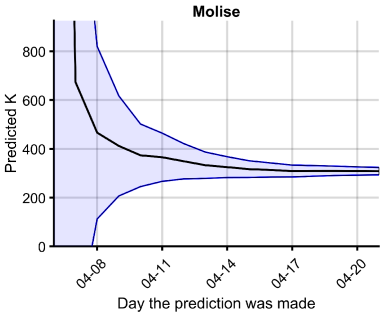

Umbria
Predicted K
Day the prediction was made


Sardegna
Predicted K
Day the prediction was made

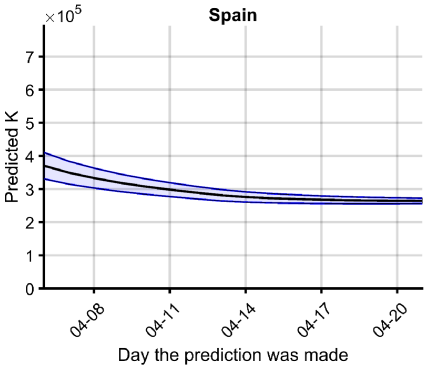

Valle dAosta
Predicted K
Day the prediction was made

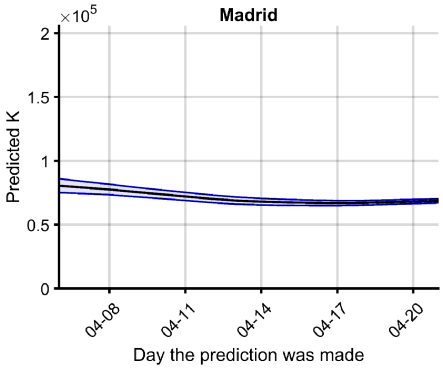

Calabria
Predicted K
Day the prediction was made

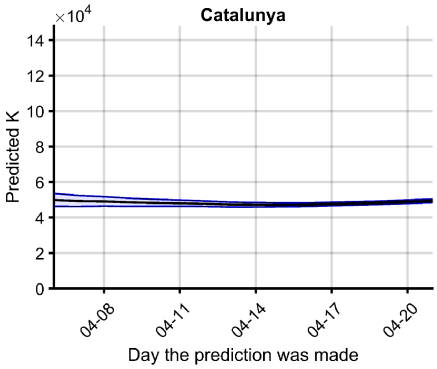

Basilicata
Predicted K
Day the prediction was made

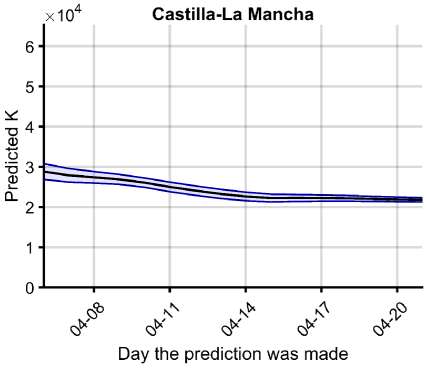

Molise
Predicted K
Day the prediction was made

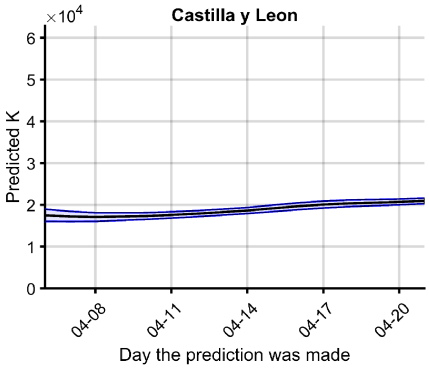
2020-04-22

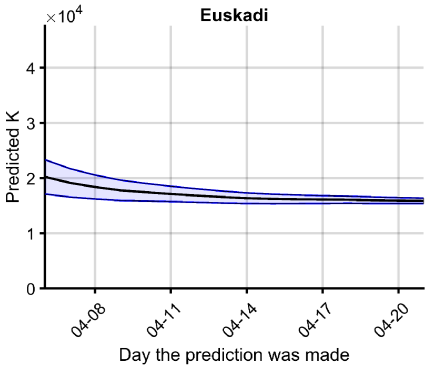

Spain
×10^5
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

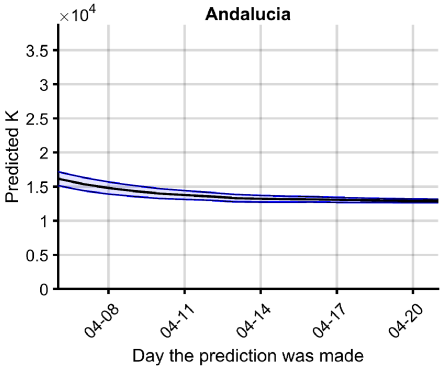

Madrid
×10^5
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

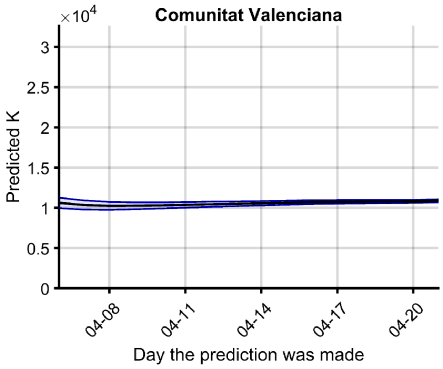

Catalunya
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

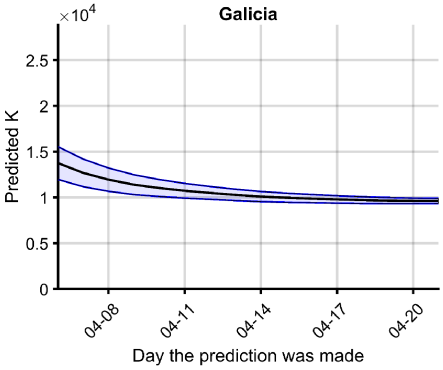

Castilla-La Mancha
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

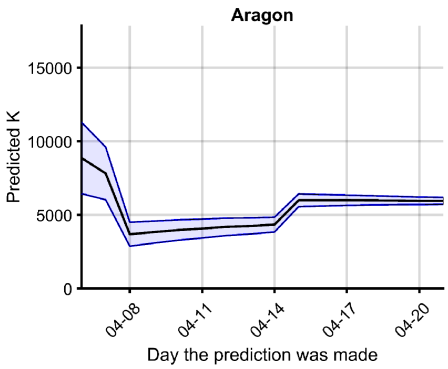

Castilla y Leon
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

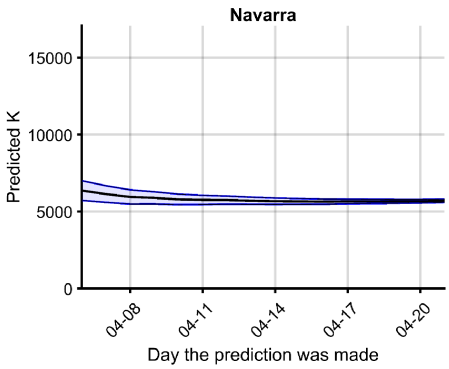

Euskadi
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

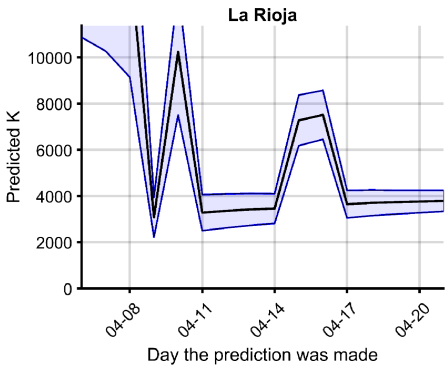

Andalucia
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

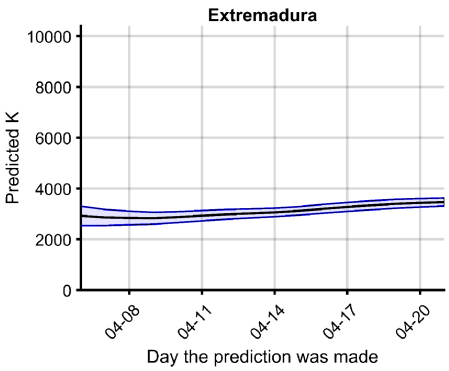

Comunitat Valenciana
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

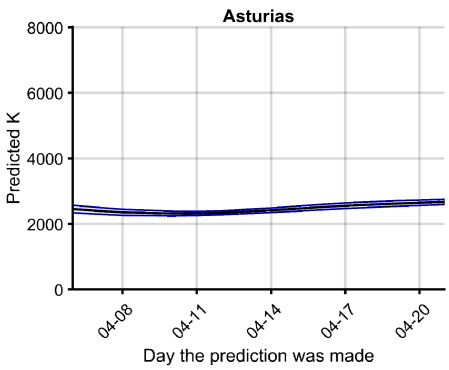

Galicia
×10^4
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

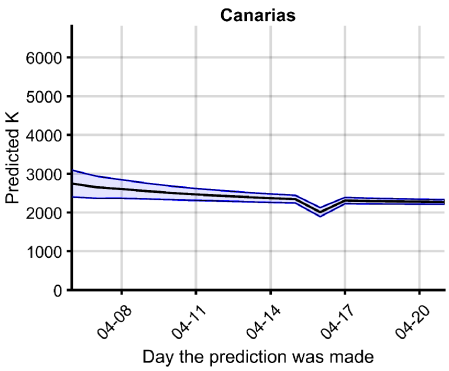

Aragon
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

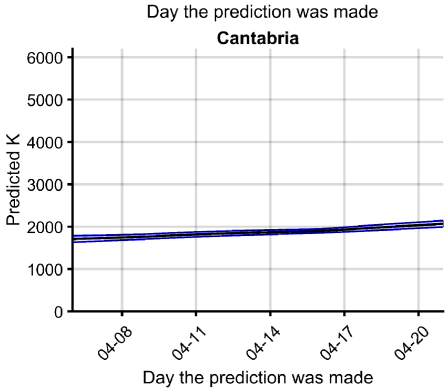

Navarra
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

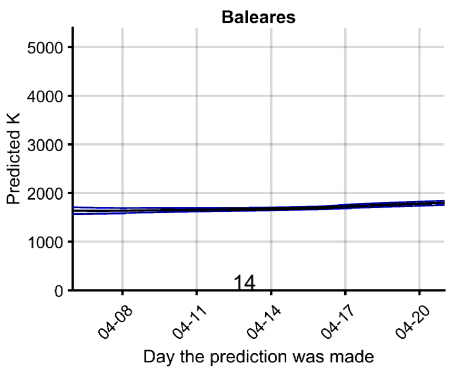

La Rioja
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

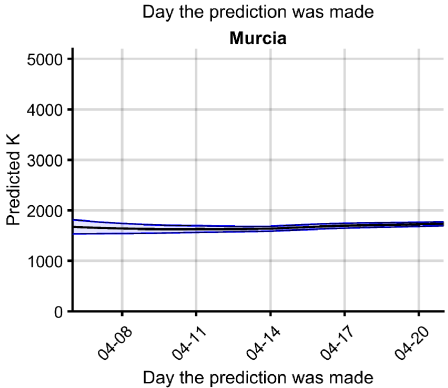

Extremadura
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20


Asturias
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20


Canarias
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20


Cantabria
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20


Baleares
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20


Murcia
Predicted K
Day the prediction was made
04-08
04-11
04-14
04-17
04-20

Situation and tendencies in Italian and Spanish regions

Italy

	Reported data						Indexes		
Country	Cumulative cases	Attack rate / 10^5 inh.	Cumulative deaths	Mortality / 10^5 inh.	Active cases (last 14 days)	14-day attack rate / 10^5 inh	Mean ρ[1]	EPG[2]	EPG2[2]
Lombardia	69,092	688.0	12,740	126.9	15,678	156.1	0.95	148.2	140.8
Emilia Romagna	23,434	525.5	3,204	71.8	5,200	116.6	0.93	108.3	100.5
Piemonte	22,739	522.0	2,559	58.7	8,856	203.3	0.85	171.9	145.3
Veneto	16,738	341.2	1,181	24.1	4,328	88.2	1.06	93.9	99.9
Toscana	8,700	233.3	705	18.9	2,321	62.2	0.72	44.5	31.8
Liguria	6,918	446.1	1,022	65.9	2,012	129.8	1.05	136.7	143.9
Lazio	5,975	101.6	370	6.3	1,709	29.1	0.61	17.8	10.9
Marche	5,924	388.4	845	55.4	1,065	69.8	0.74	51.4	37.8
Campania	4,185	72.1	327	5.6	917	15.8	0.71	11.3	8.0
Puglia	3,730	92.6	362	9.0	1,096	27.2	1.10	29.9	32.8
Trento	3,646	340.0	381	35.5	1,044	97.4	0.95	92.7	88.2
Sicilia	2,883	57.7	208	4.2	724	14.5	1.27	18.4	23.4
Friuli Venezia Giulia	2,817	231.8	246	20.2	599	49.3	0.60	29.7	17.8
Abruzzo	2,733	208.4	276	21.0	874	66.6	1.30	86.8	113.0
Bolzano	2,416	2,248.8	256	238.3	581	540.8	0.61	328.0	198.9
Umbria	1,357	153.9	61	6.9	68	7.7	1.85	14.3	26.5
Sardegna	1,247	76.1	96	5.9	272	16.6	0.97	16.0	15.5
Valle dAosta	1,095	871.8	127	101.1	245	195.1	1.06	206.4	218.4
Calabria	1,060	54.4	76	3.9	201	10.3	0.71	7.4	5.2
Basilicata	354	62.9	24	4.3	57	10.1	0.77	7.8	6.0
Molise	284	92.9	19	6.2	58	19.0	1.53	29.0	44.3
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	500.0	500.0
	Best	Best	Best	Best	Best	Best	0.0	0.0	0.0

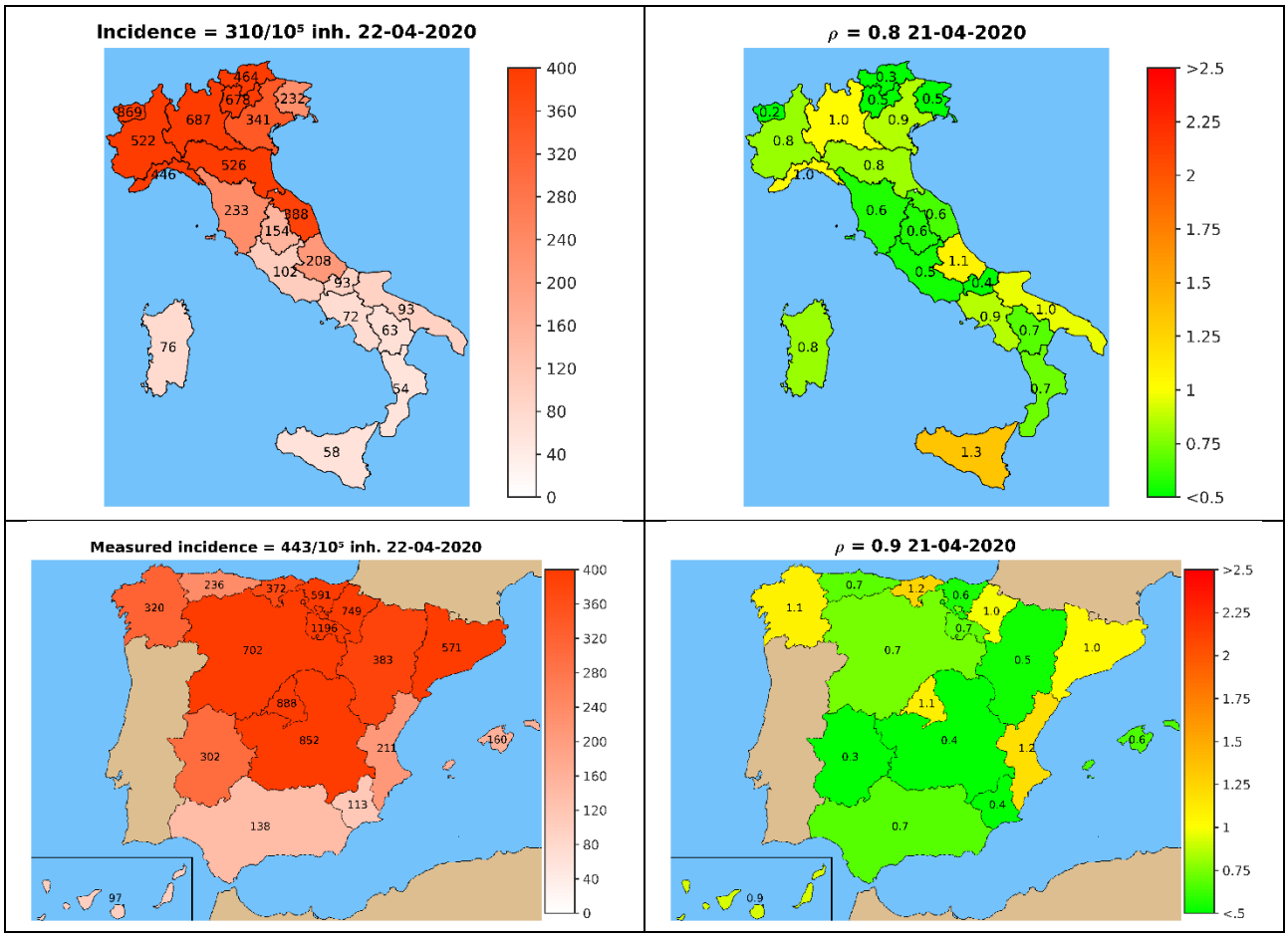
Spain

	Reported data						Indexes		
Autonomous regions	Cumulative cases	Attack rate /10^5 inh.	Cumulated deaths	Mortality rate /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	Mean ρ[1]	EPG[2]	EPG2[2]
Madrid	59,199	891.5	7,577	114.1	16,749	252.2	1.40	353.8	496.3
Catalunya	43,802	579.0	4,247	56.1	14,155	187.1	1.2	223.8	267.7
Castilla-La Mancha	17,321	850.9	2,140	105.1	7,263	356.8	0.87	309.6	268.6
Castilla y Leon	16,839	699.3	1,554	64.5	5,051	209.8	0.2	35.4	6.0
Euskadi	13,044	598.9	1,124	51.6	3,592	164.9	0.64	104.8	66.6
Andalucia	11,610	137.8	1,050	12.5	2,613	31.0	0.68	21.2	14.5
Comunitat Valenciana	10,538	211.8	1,106	22.2	2,883	58.0	0.74	42.9	31.8
Galicia	8,634	319.7	368	13.6	2,096	77.6	0.95	74.0	70.6
Aragon	5,054	382.6	656	49.7	1,505	113.9	0.61	69.4	42.3
Navarra	4,899	753.7	401	61.7	1,432	220.3	0.94	206.7	193.9
La Rioja	3,792	1,209.3	298	95.0	841	268.2	0.84	226.6	191.4
Extremadura	3,230	303.2	404	37.9	1,046	98.2	0.57	56.1	32.0
Asturias	2,419	236.6	211	20.6	714	69.8	0.56	39.4	22.2
Cantabria	2,160	371.3	167	28.7	588	101.1	2.00	202.5	405.5
Canarias	2,094	94.9	121	5.5	332	15.0	1.03	15.4	15.8
Baleares	1,836	154.6	164	13.8	424	35.7	1.00	35.8	35.8
Murcia	1,695	113.9	123	8.3	369	24.8	0.33	8.1	2.7
Ceuta	118	139.1	4	4.7	34	40.1	ND	ND	ND
Melilla	105	123.9	2	2.4	12	14.2	ND	ND	ND
	Scale								
	Worst	Worst	Worst	Worst	Worst	Worst	2.0	500.0	500.0
	Best	Best	Best	Best	Best	Best	0.0	0.0	0.0

[1] Disclaimer: parameter ρ is very sensitive and experiments daily variations. Mean ρ is averaged per 3 consecutive days, but it can still vary the following days. [2] EPG stands for Effective Growth Potential. It is obtained by multiplying attack rate per 10^5 inhabitants of last 10 days (i.e. density of cases) by ρ (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). EPG2 is a similar index but attack rate of last 10 days is multiplied by ρ^2.

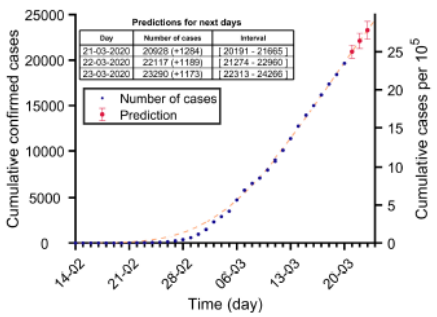
Maps of Italian and Spanish regions

Cumulated incidence and spreading rate (ρ) in Europe, Italian regions and Spanish autonomous communities.

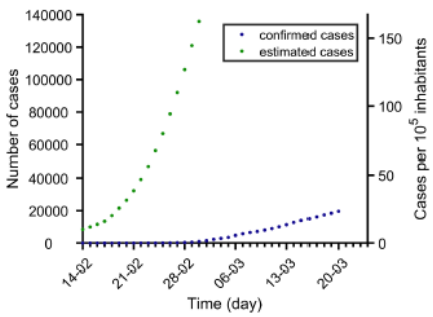


Legend: Countries' reports details

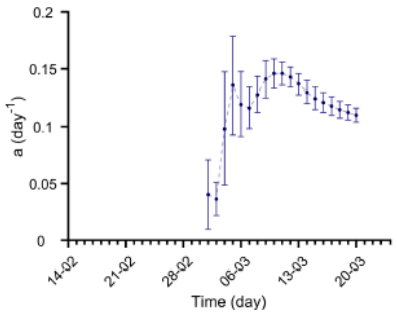
Iran 20-03-2020. Population: 83.7M. Current cumulated incidence: $23/10^5$



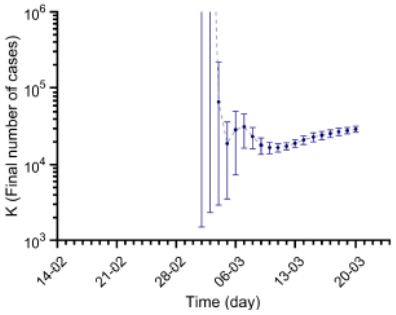
Confirmed cases: data (blue), model fitted (dashed line), predictions (red points and table)



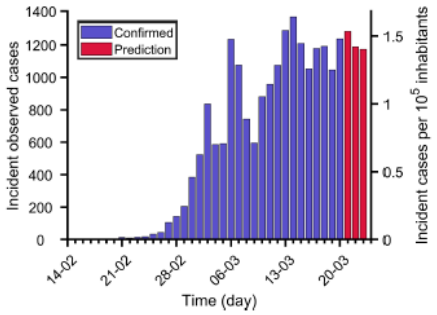
Estimated cases using death rate (see Methods)



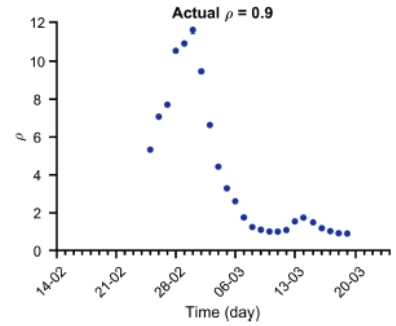
Fitted *a* value using points prior to each date



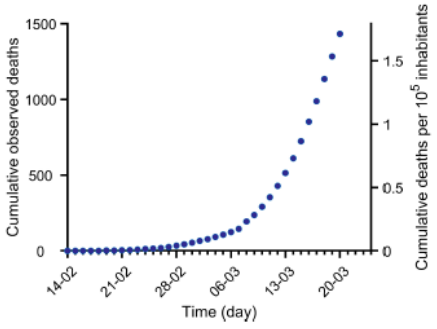
Fitted *K* value using points prior to each date



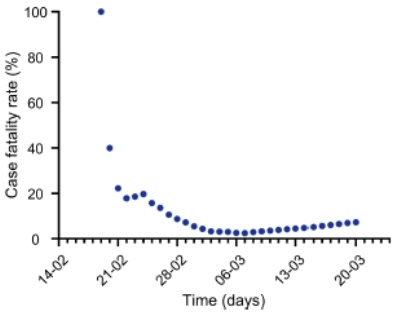
Reported and predicted new cases



Evolution of ρ, a parameter related with Reproduction number (see Methods)



Reported deaths



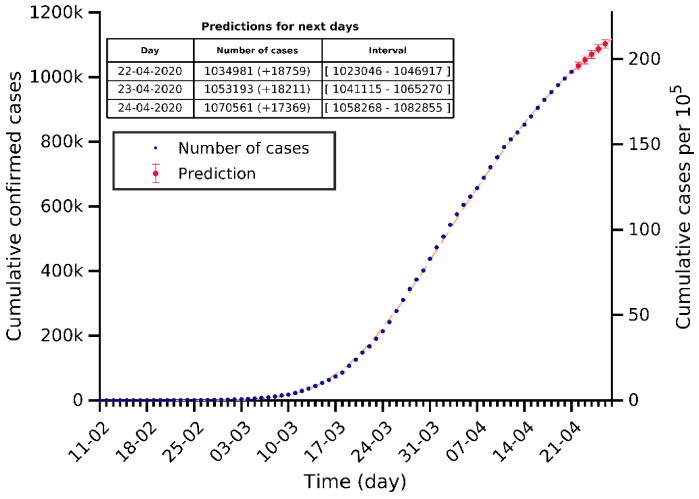
Deaths / cumulated reported cases

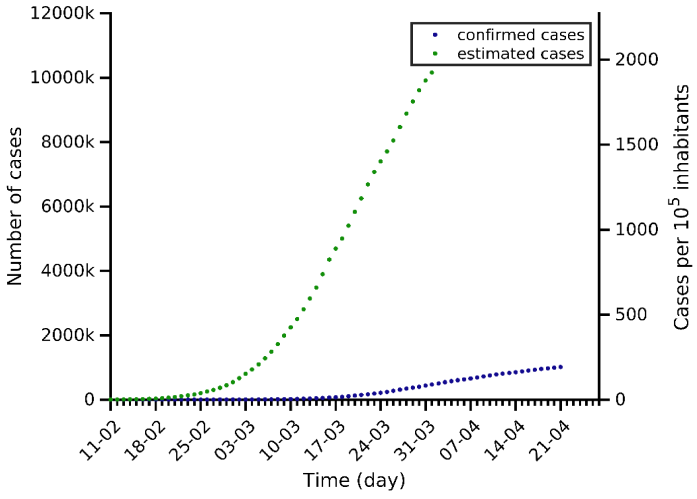
(1) Analysis and prediction of COVID-19 for EU+EFTA+UK

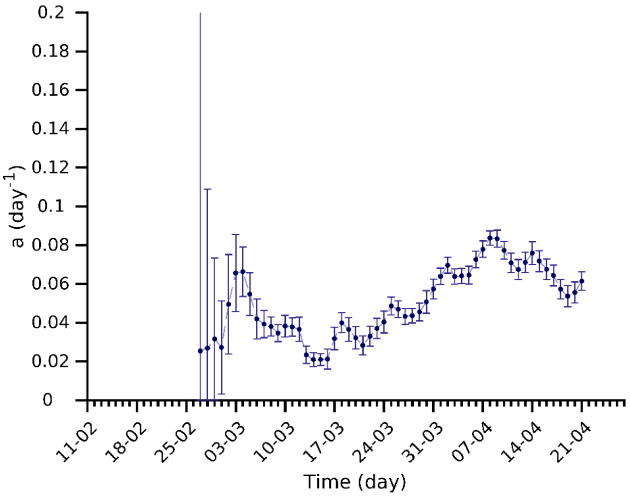
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

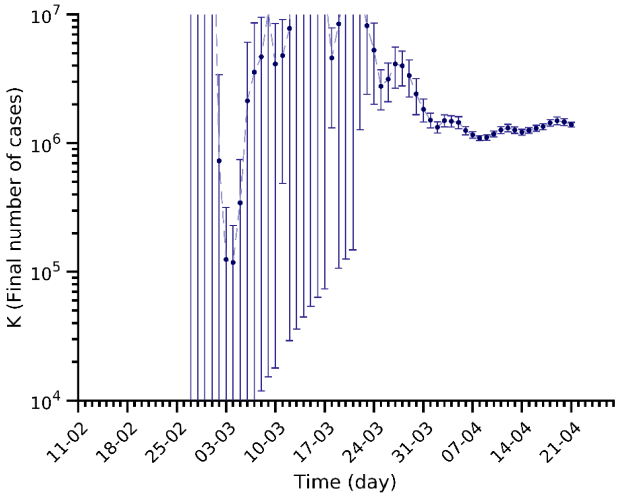
https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale (Italy)

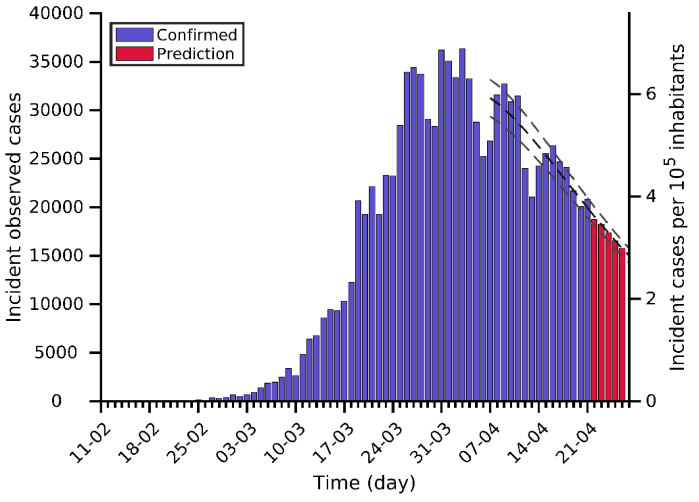
EU+EFTA+UK 21-04-2020. Population: 527.9M. Current cumulated incidence: 193/1

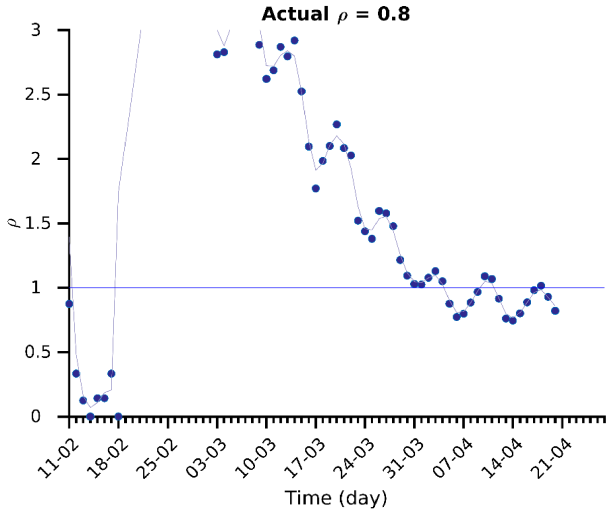


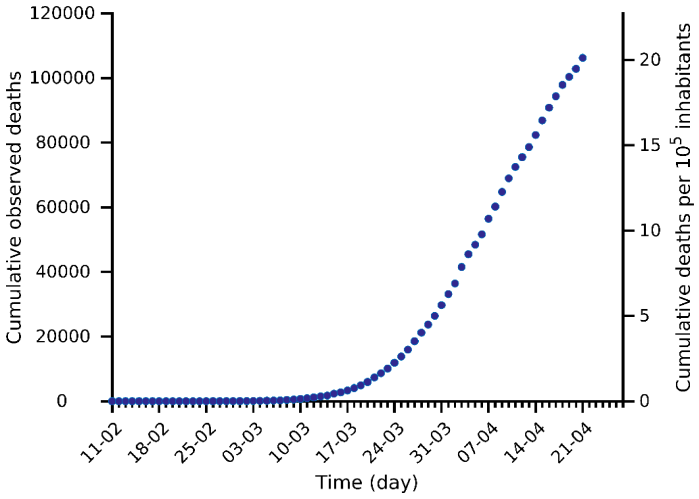


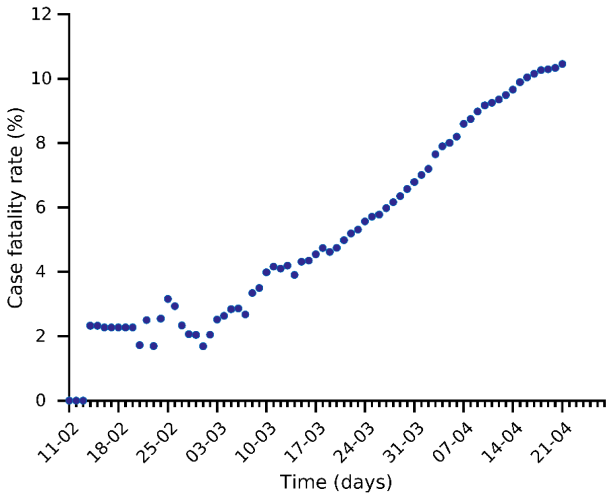




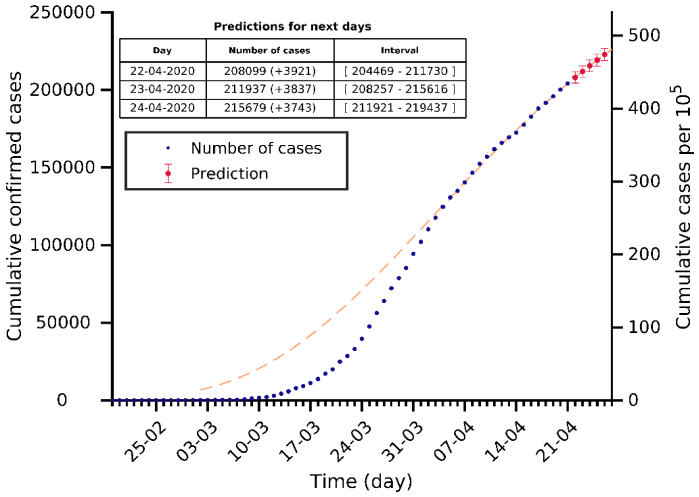


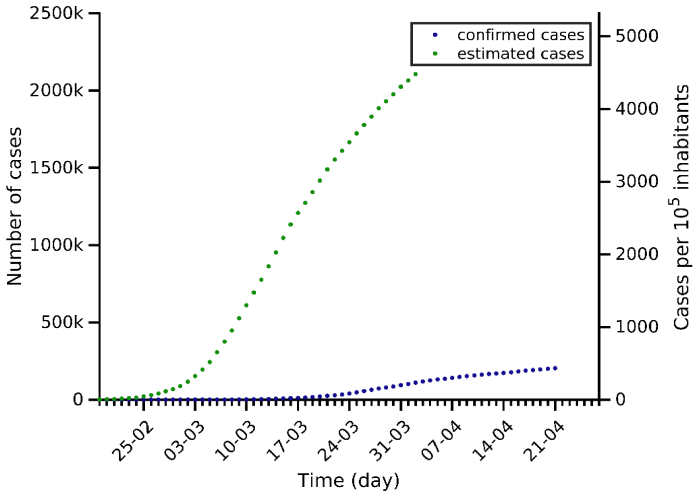


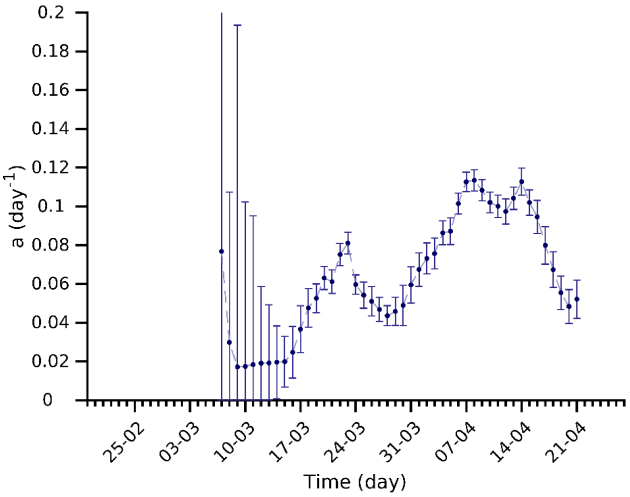


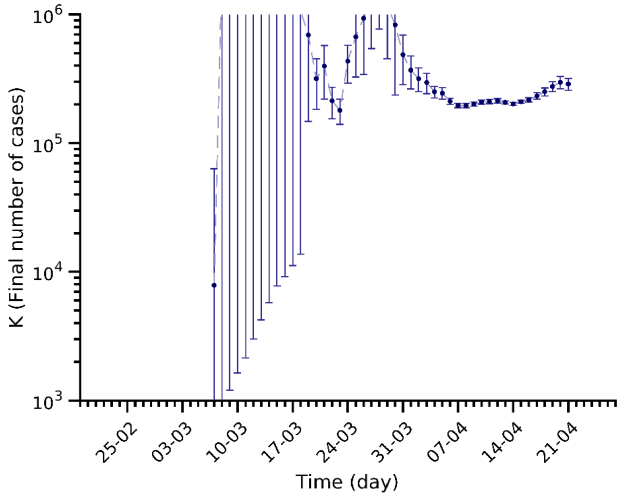


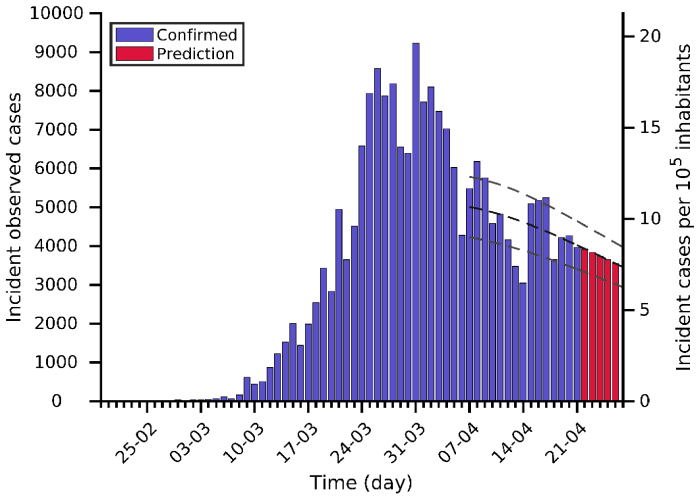
Spain 21-04-2020. Population: 47.0M. Current cumulated incidence: 434/10^5

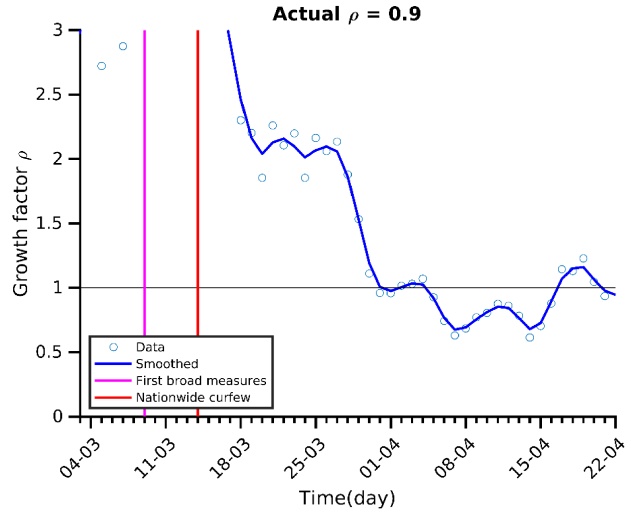


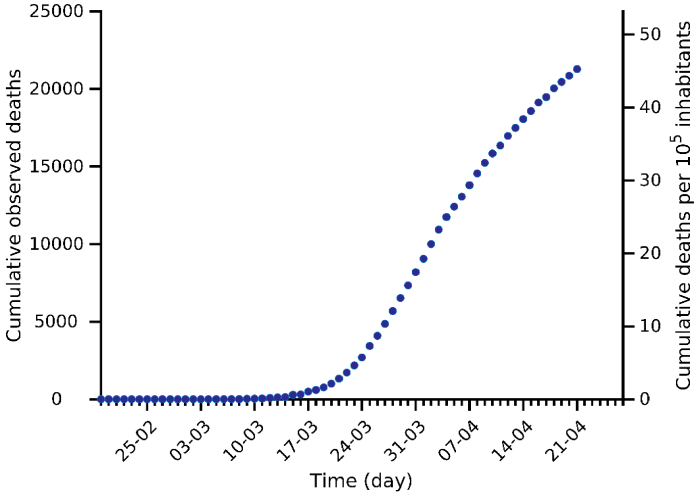


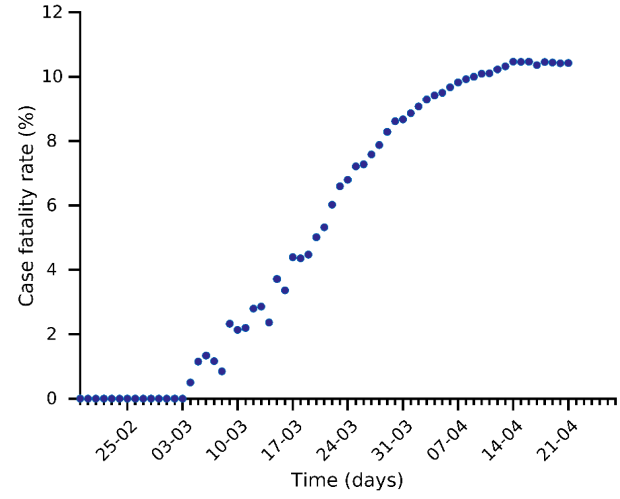




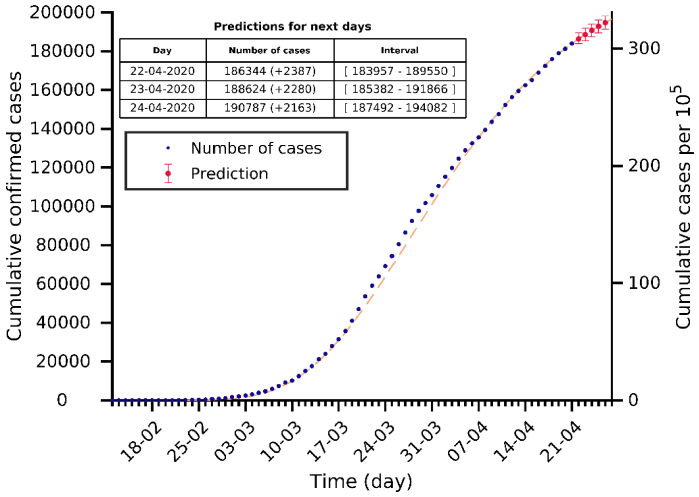


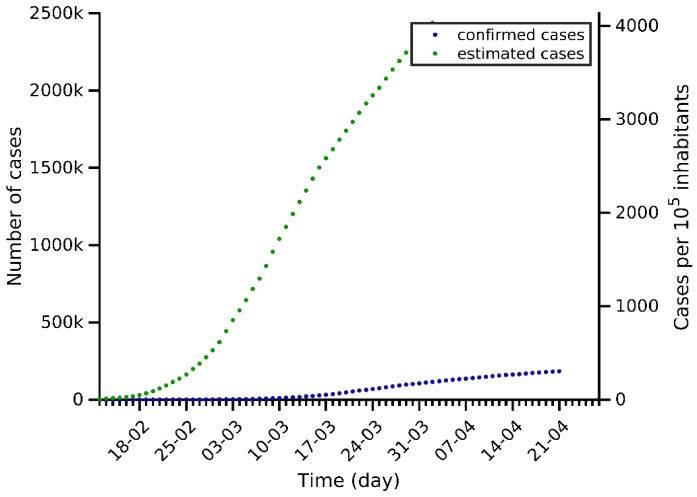


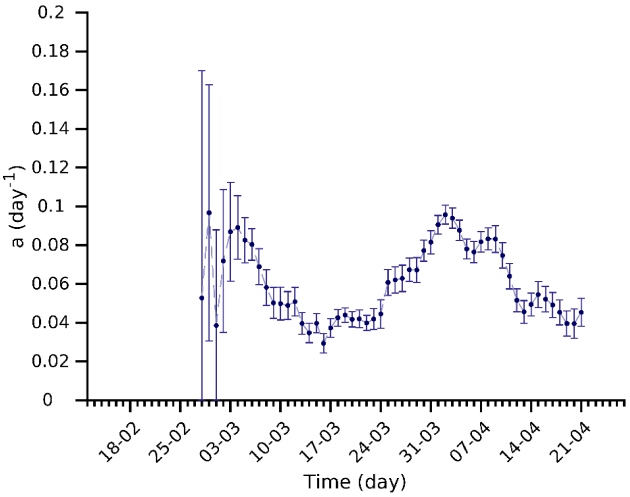


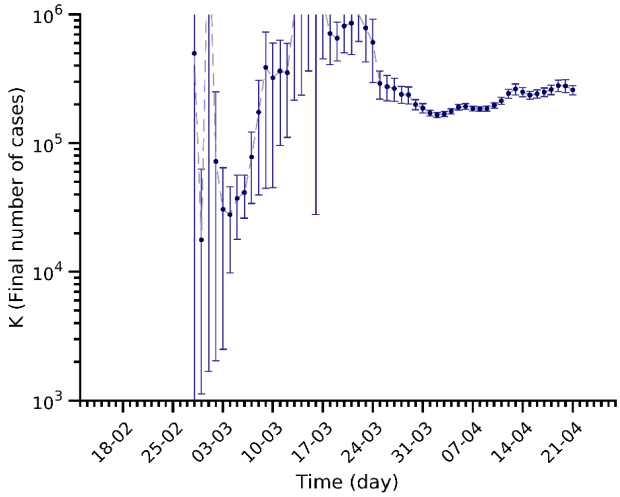


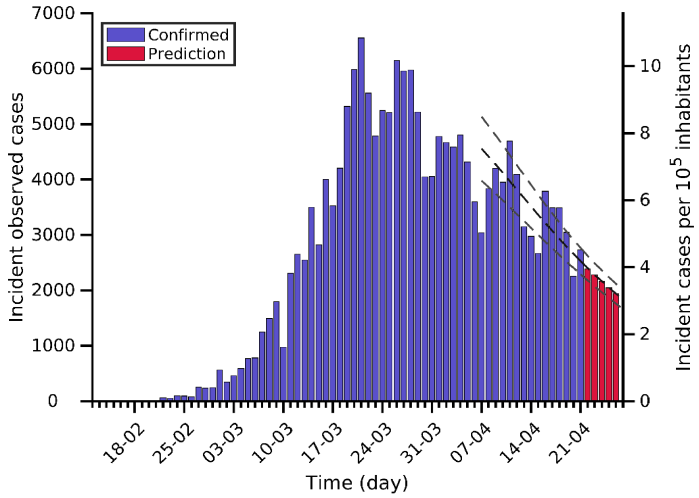
Italy 21-04-2020. Population: 60.5M. Current cumulated incidence: 304/10^5

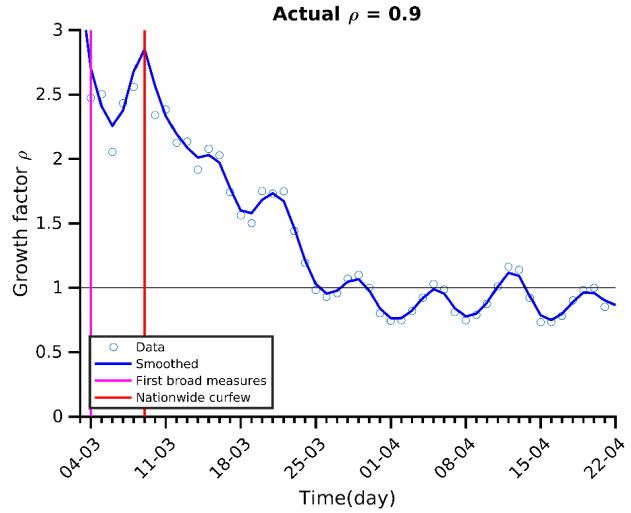


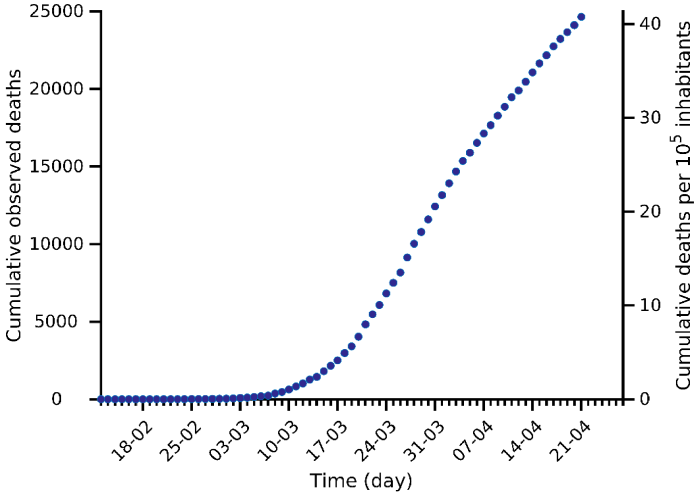


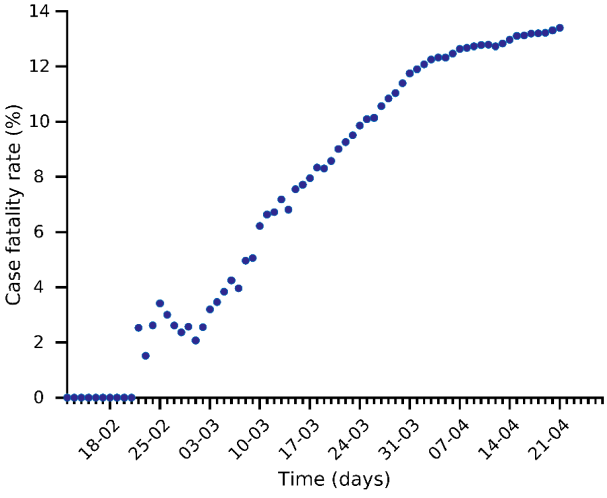




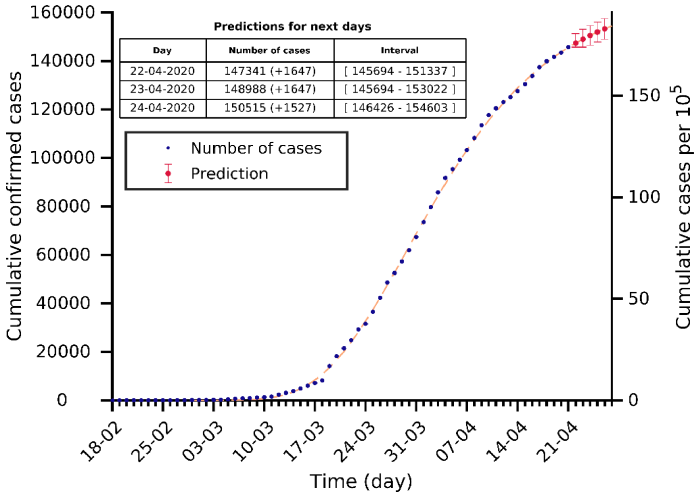


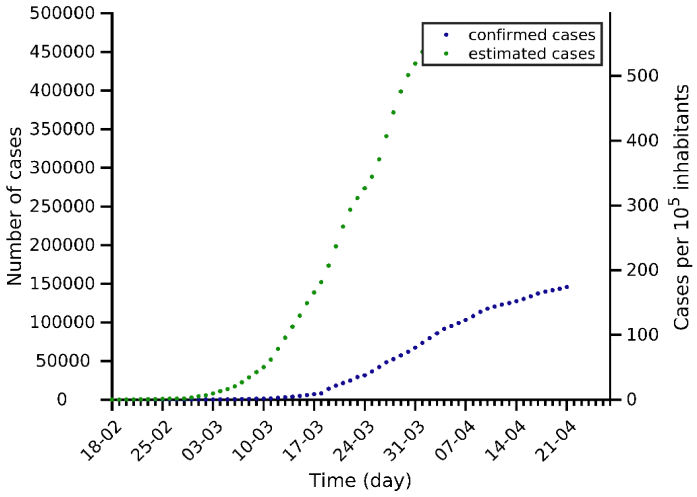


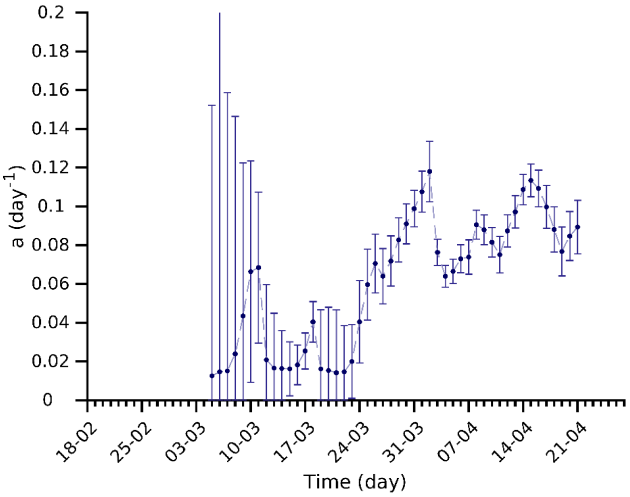


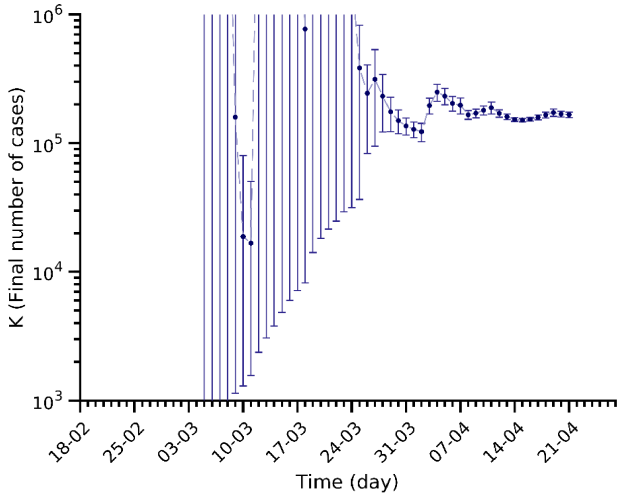


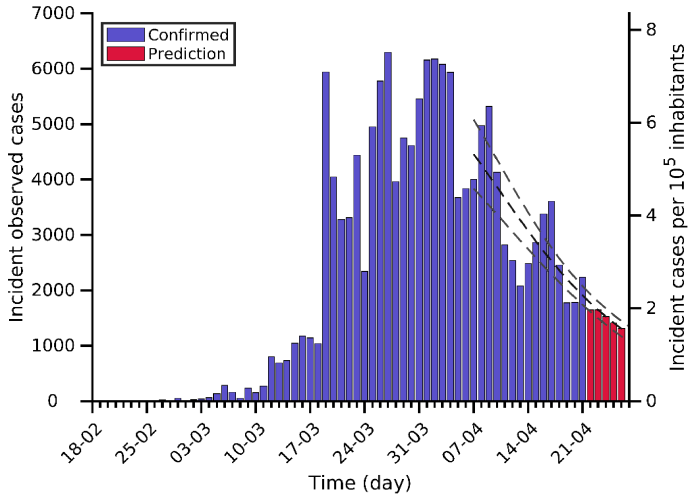
Germany 21-04-2020. Population: 83.8M. Current cumulated incidence: 174/10^5

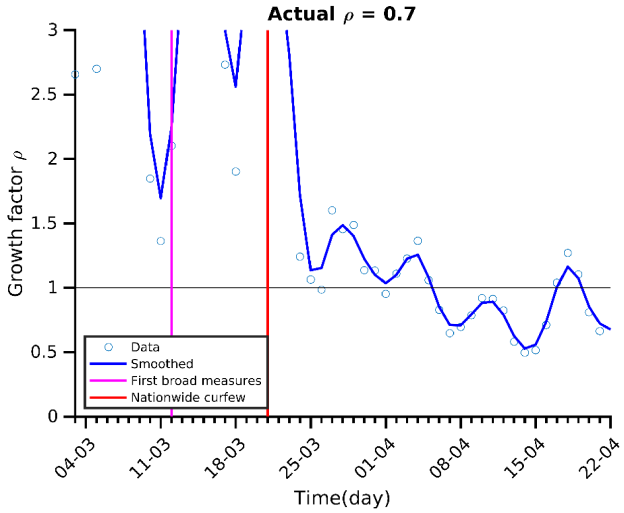


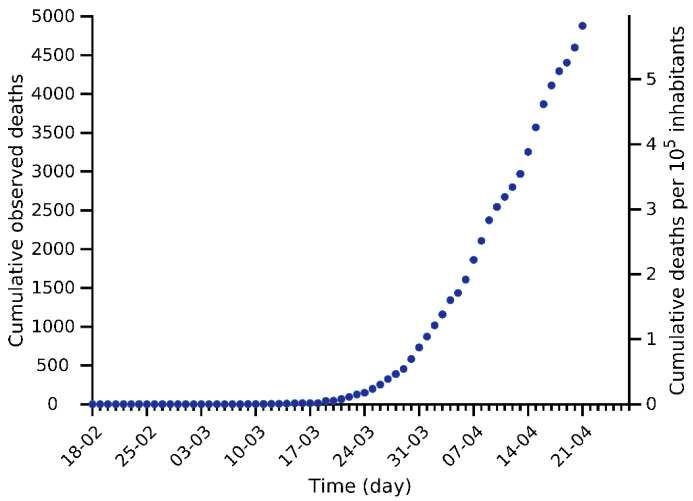


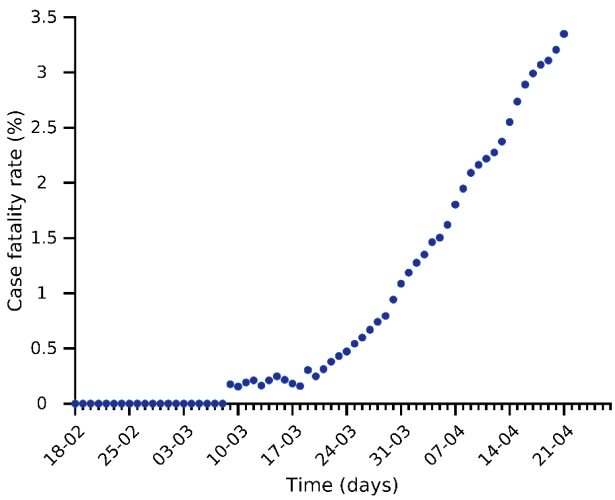




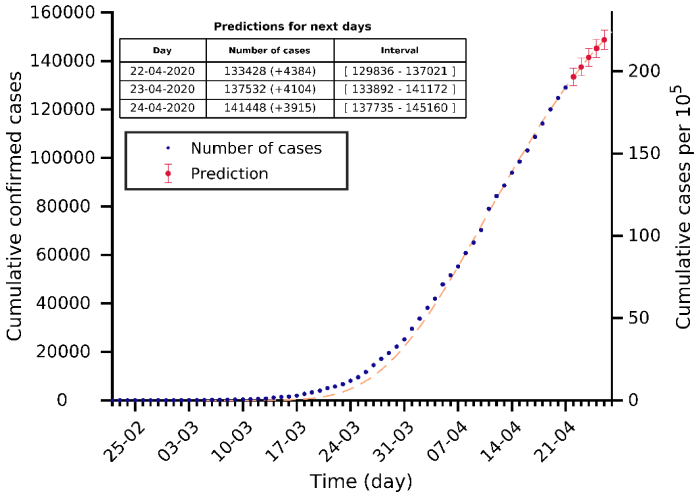


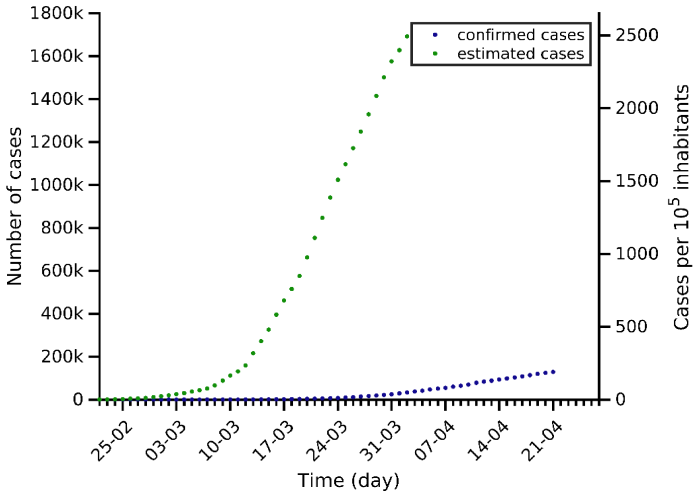


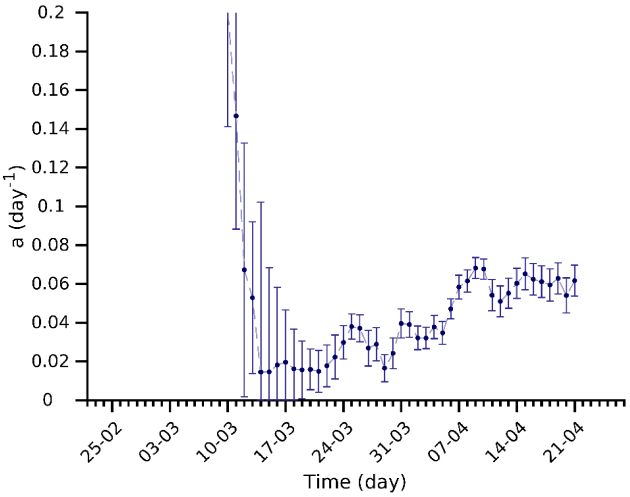


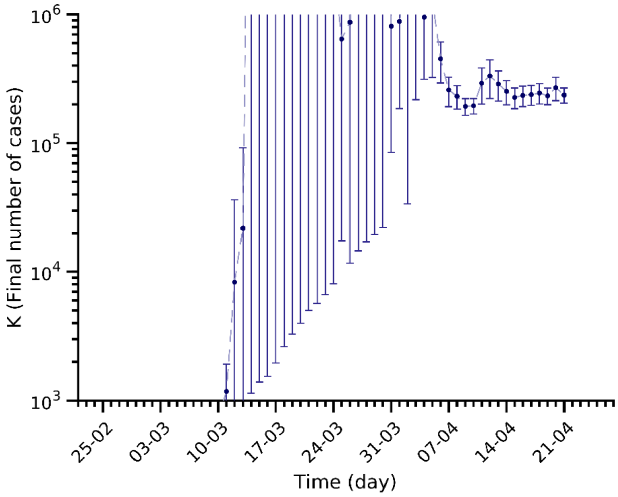


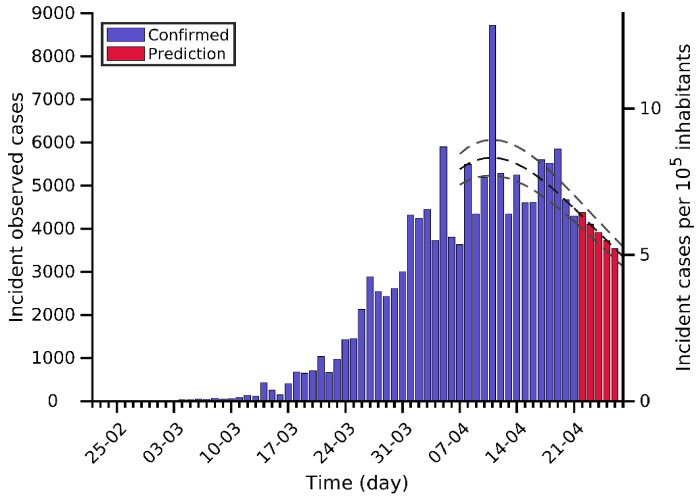
UK 21-04-2020. Population: 67.9M. Current cumulated incidence: 190/10⁵

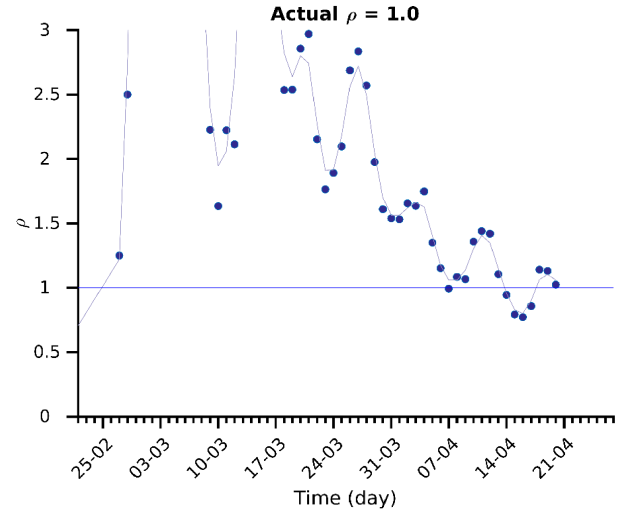


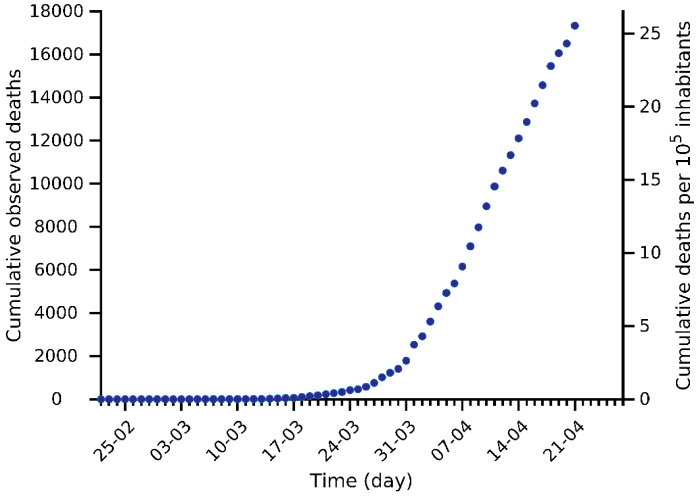


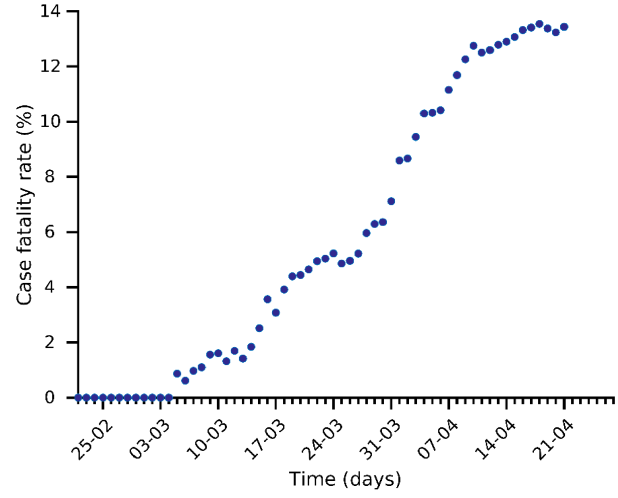




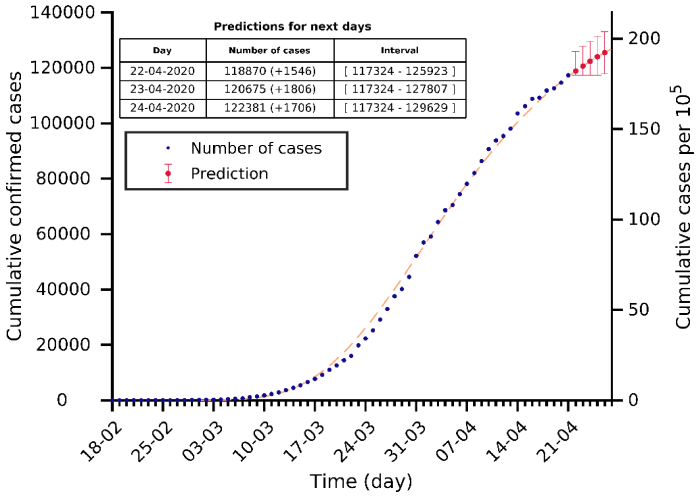


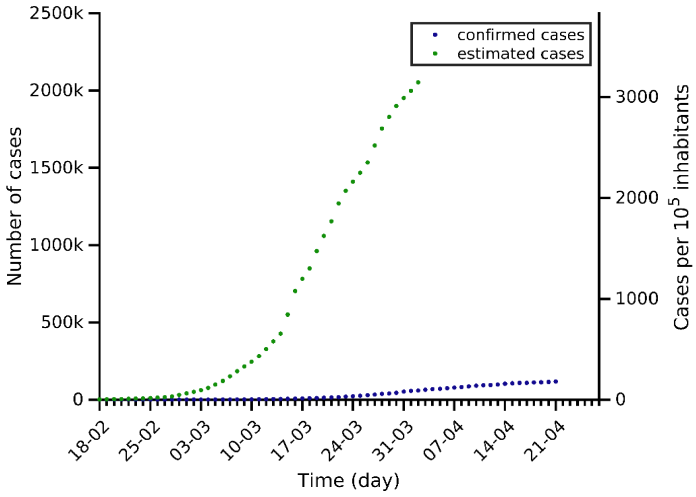


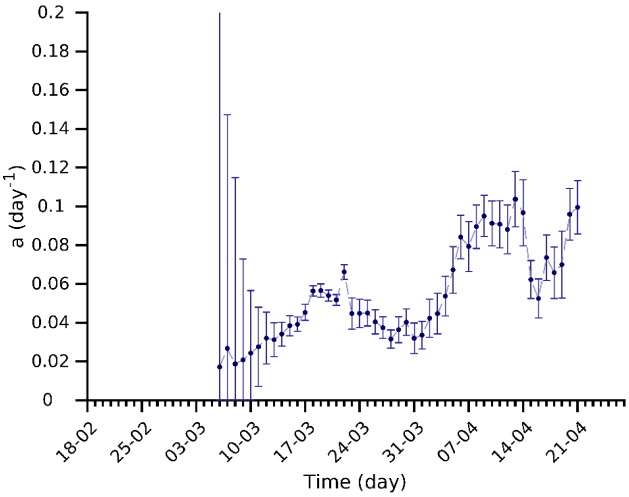


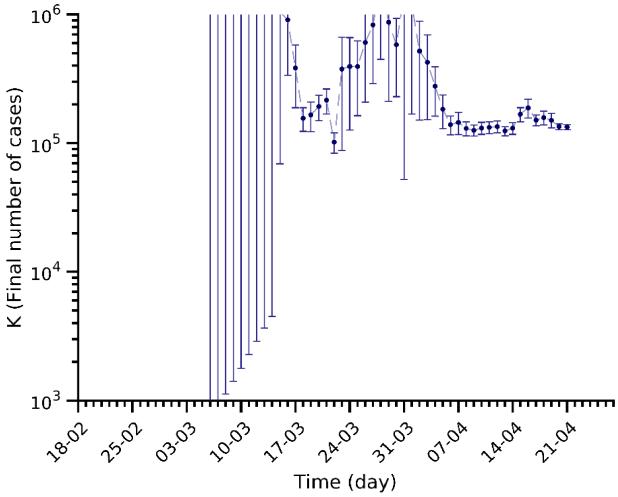


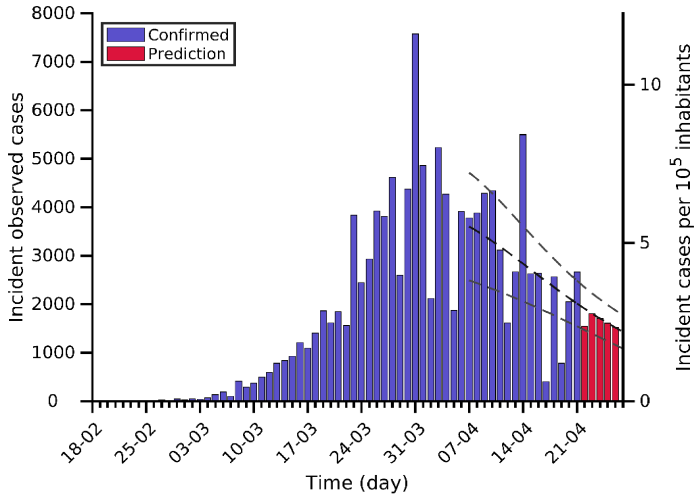
France 21-04-2020. Population: 65.3M. Current cumulated incidence: 180/10^5

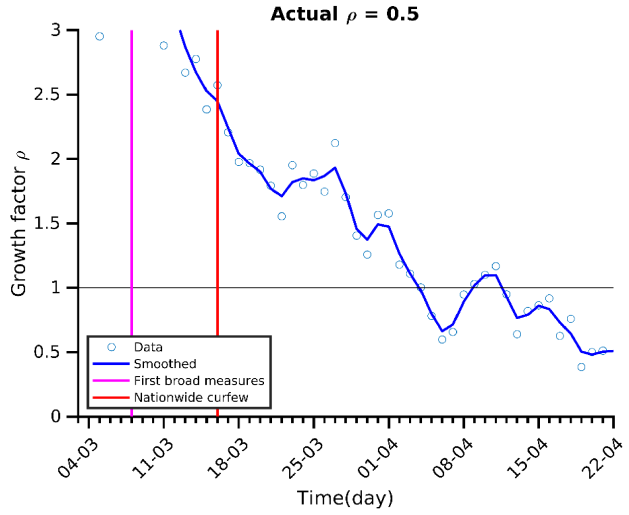


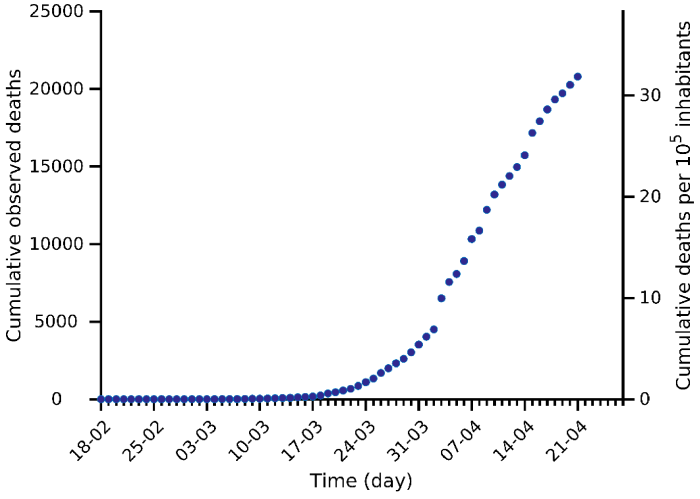


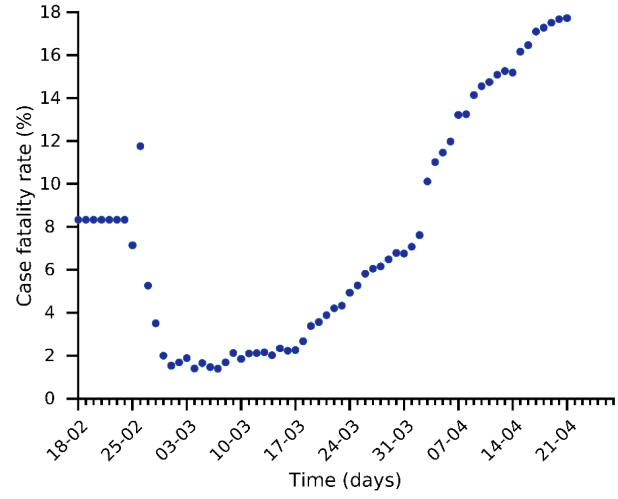




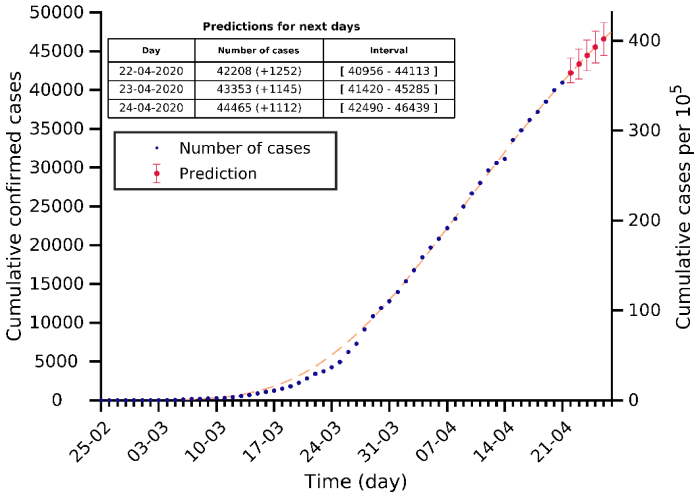


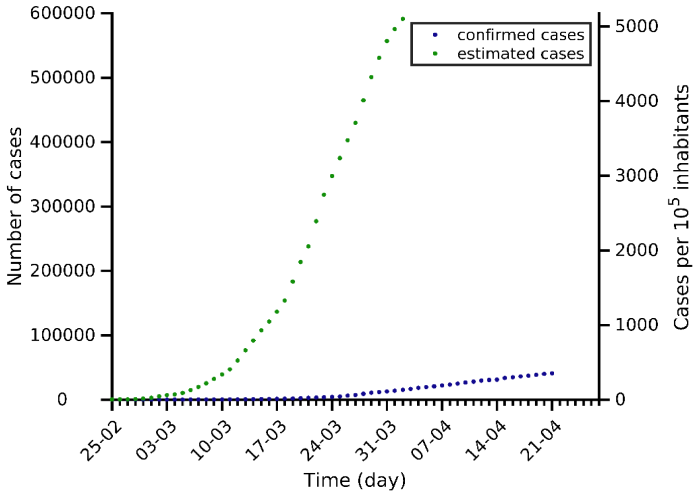


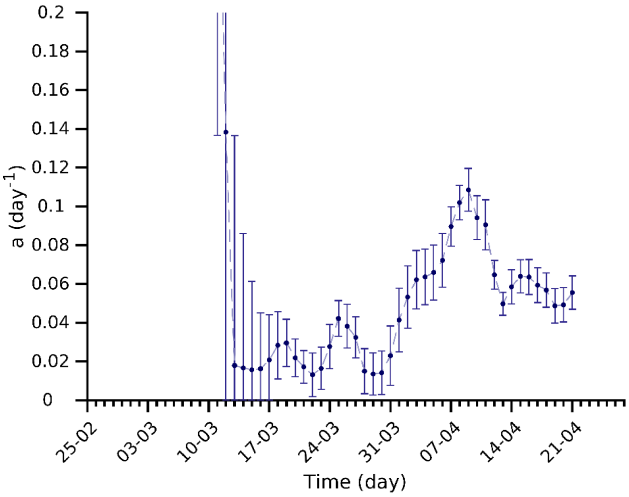


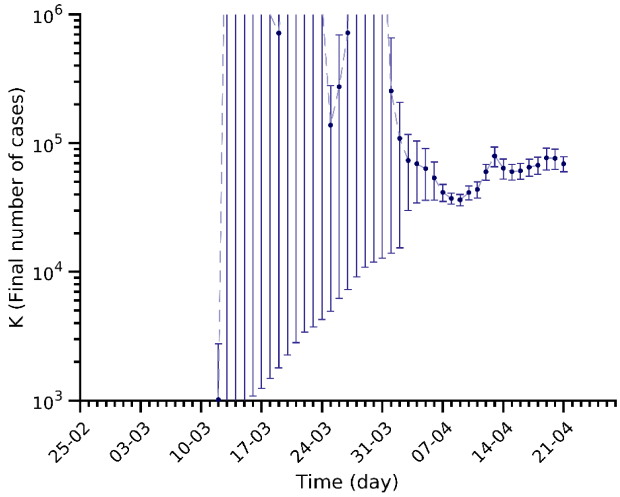


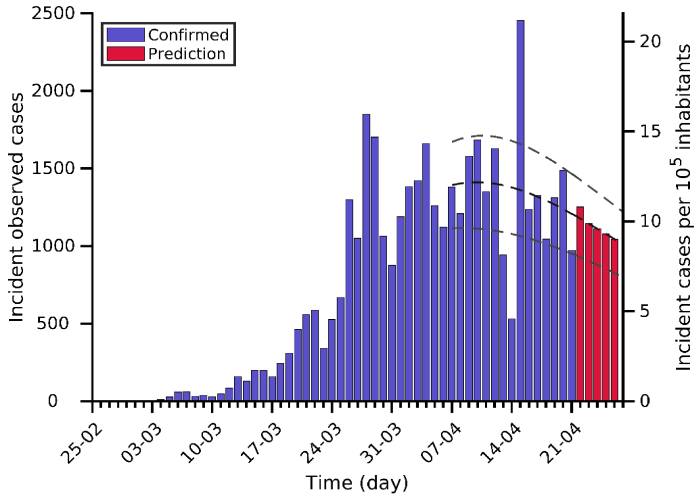
Belgium 21-04-2020. Population: 11.6M. Current cumulated incidence: 353/10^5

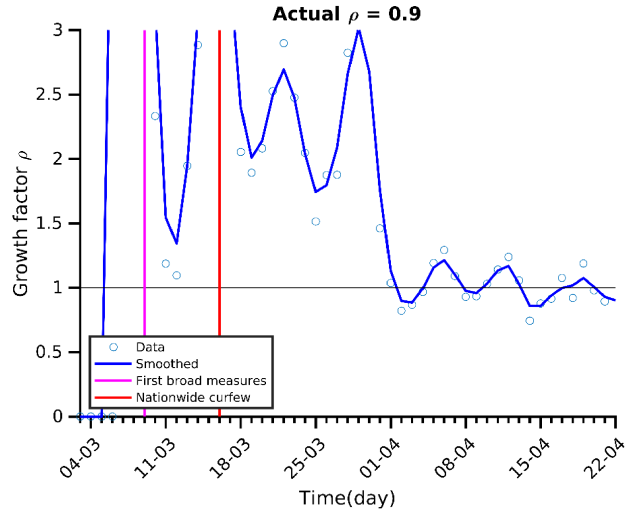


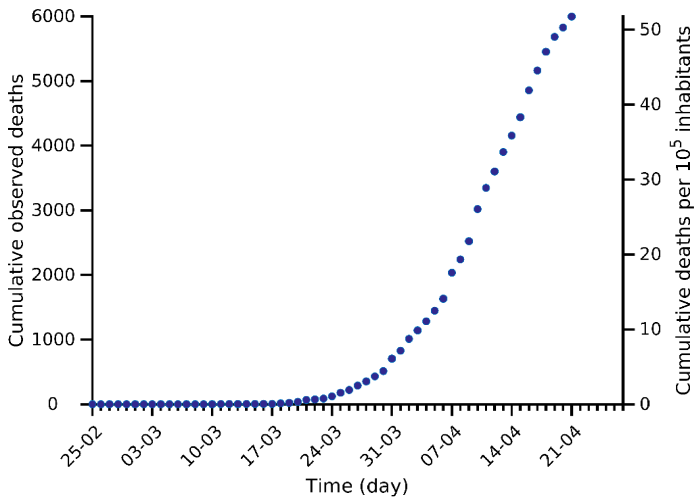


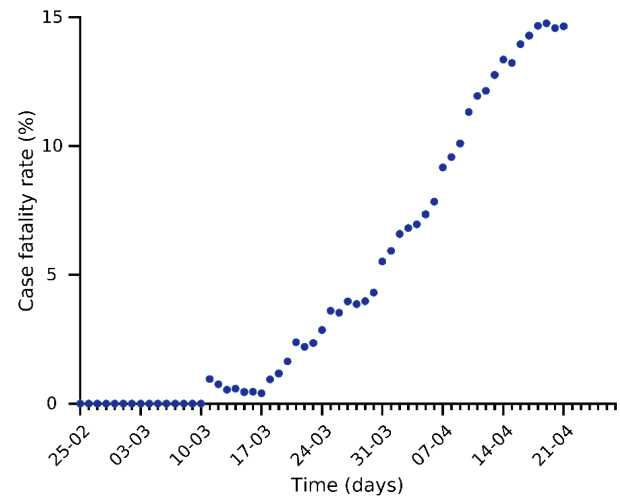




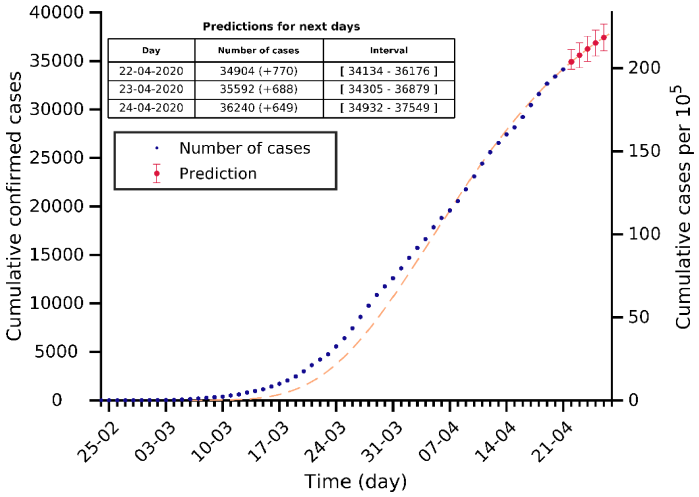


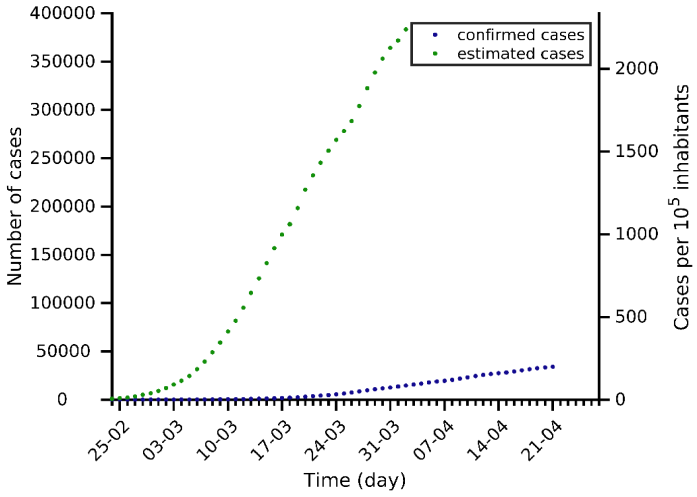


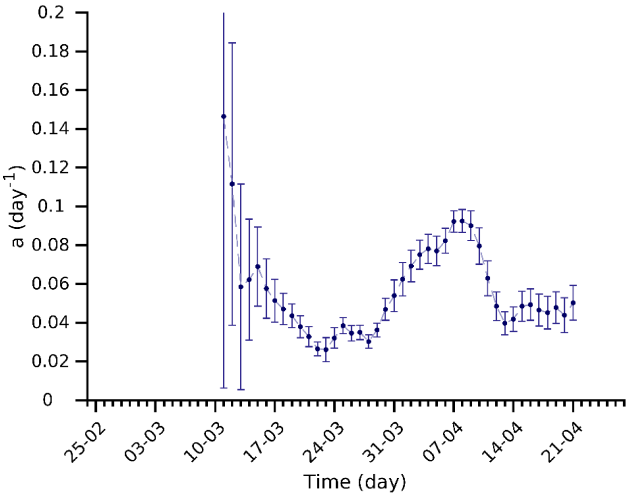


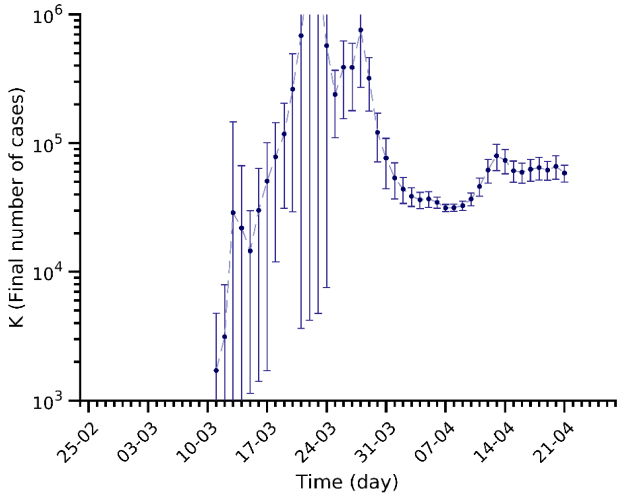


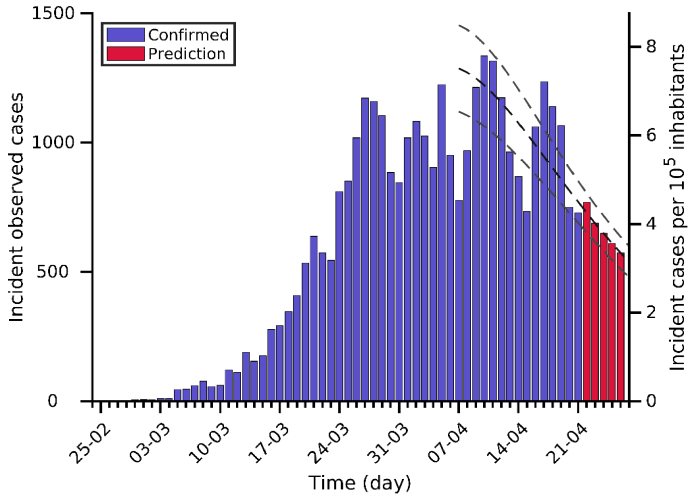
Netherlands 21-04-2020. Population: 17.1M. Current cumulated incidence: 199/10^5

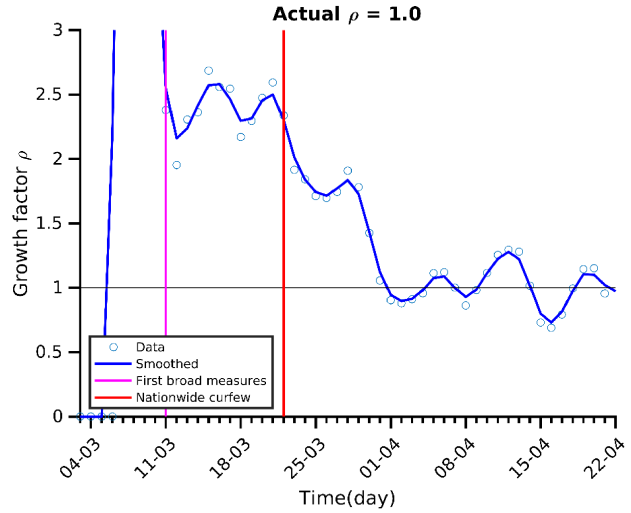


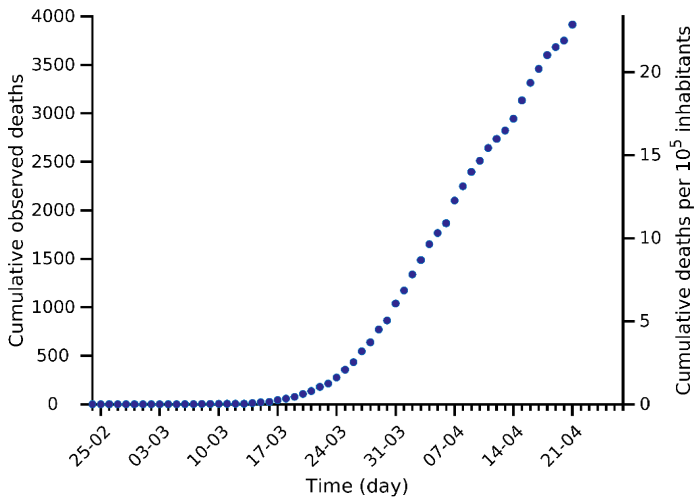


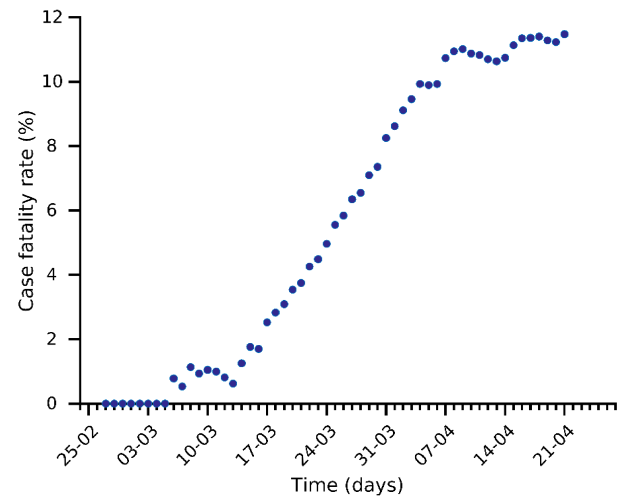




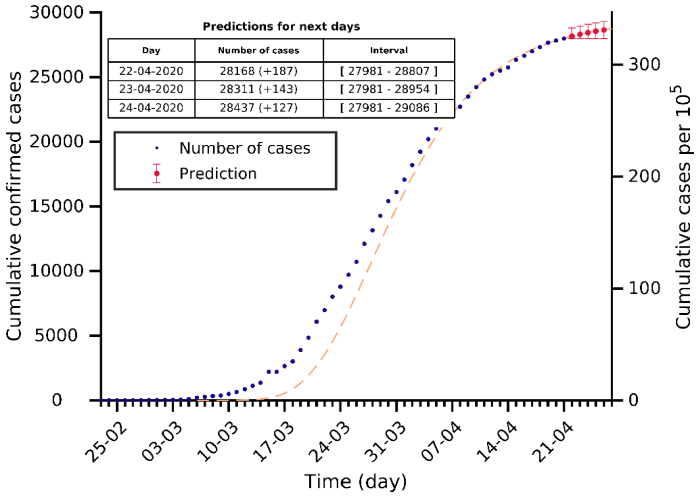


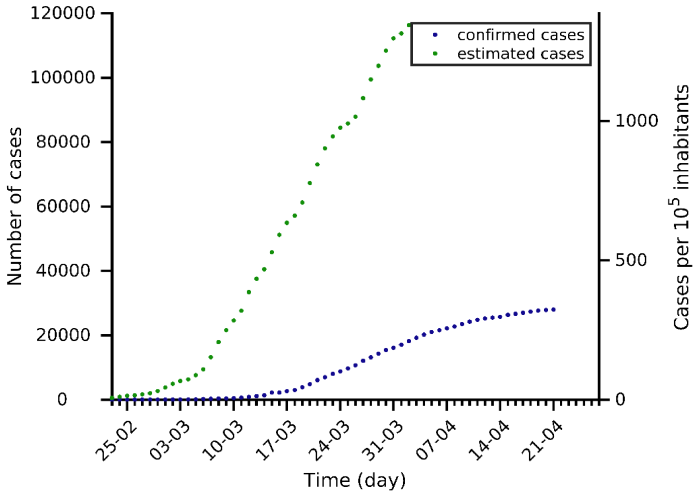


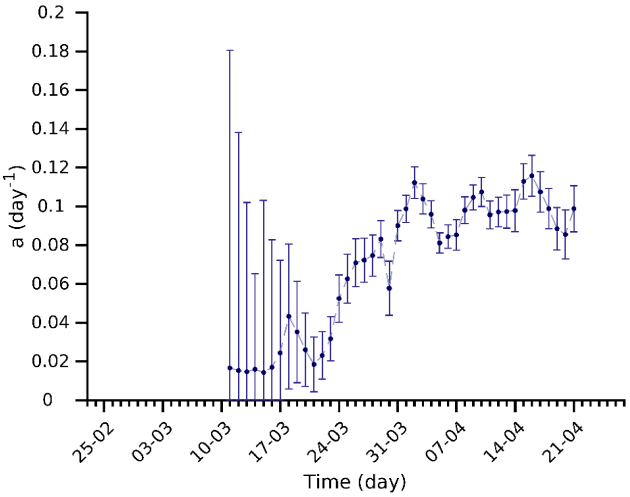


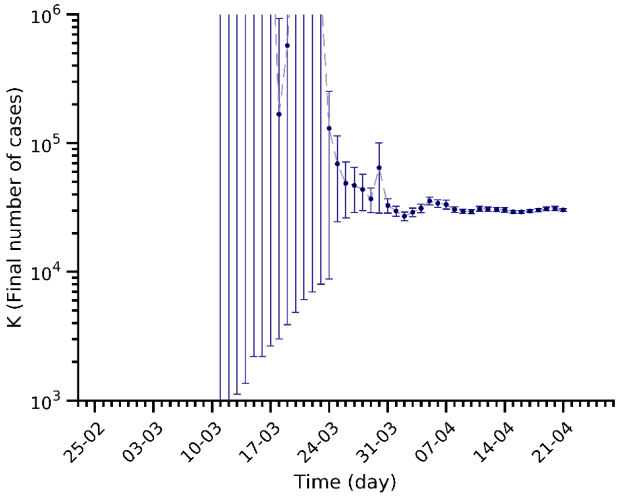


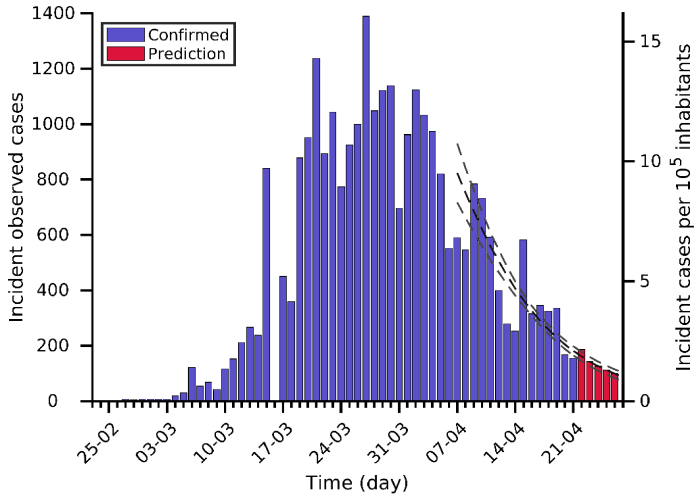
Switzerland 21-04-2020. Population: 8.7M. Current cumulated incidence: 323/10^5

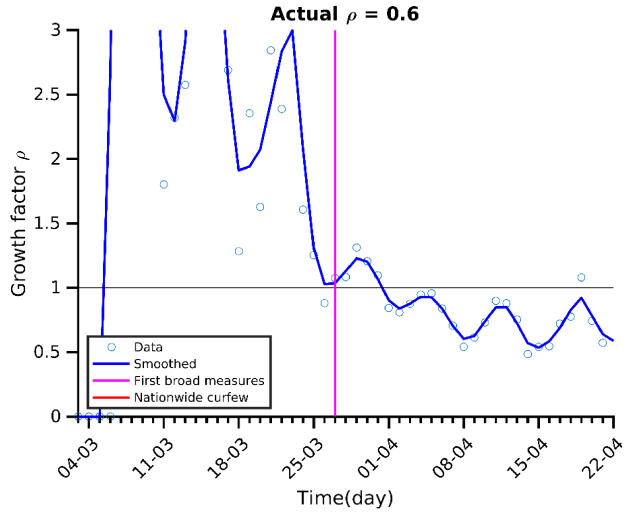


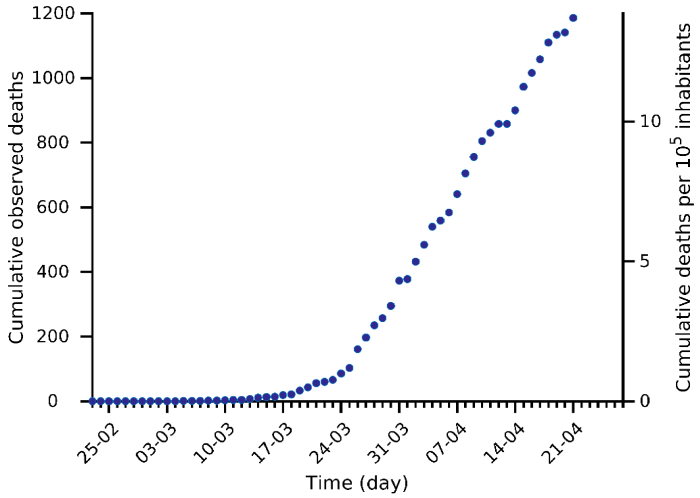


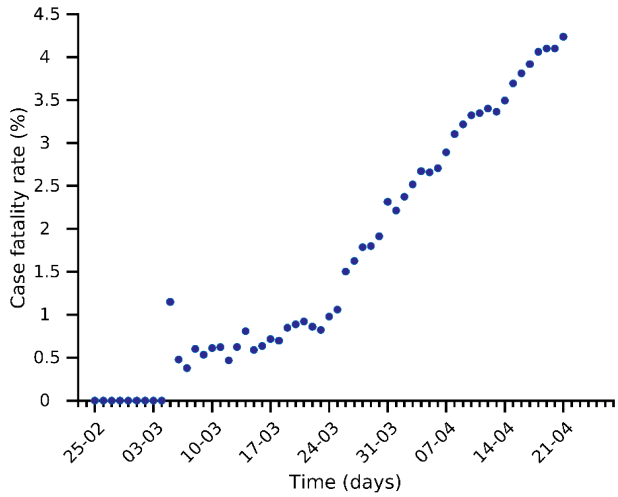




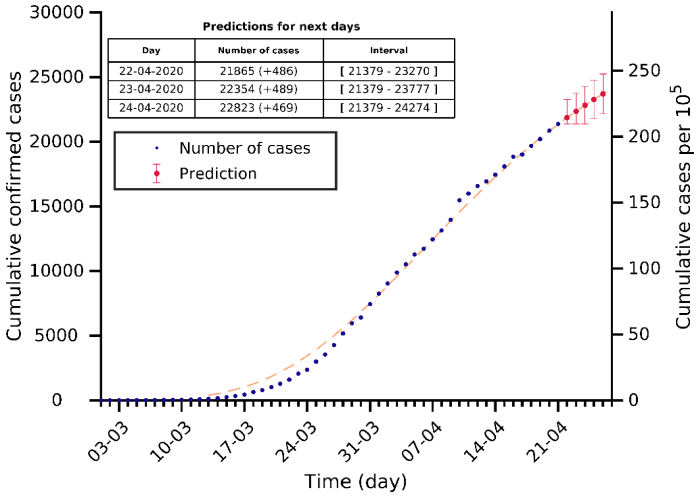


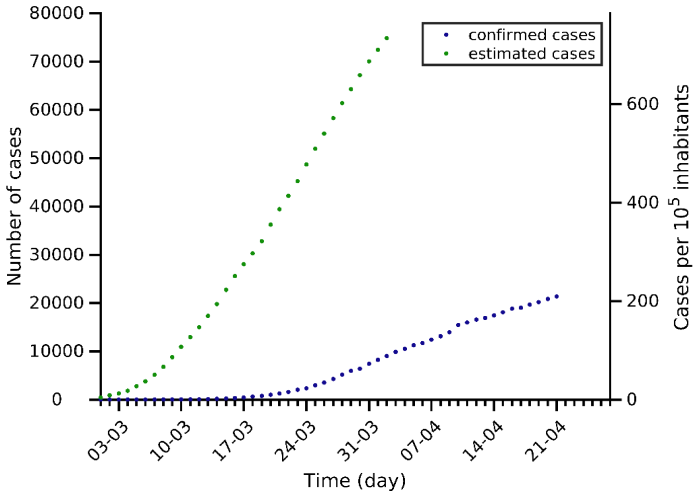


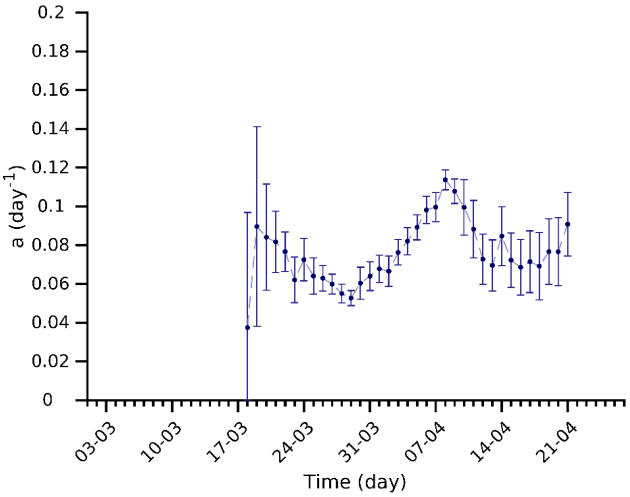


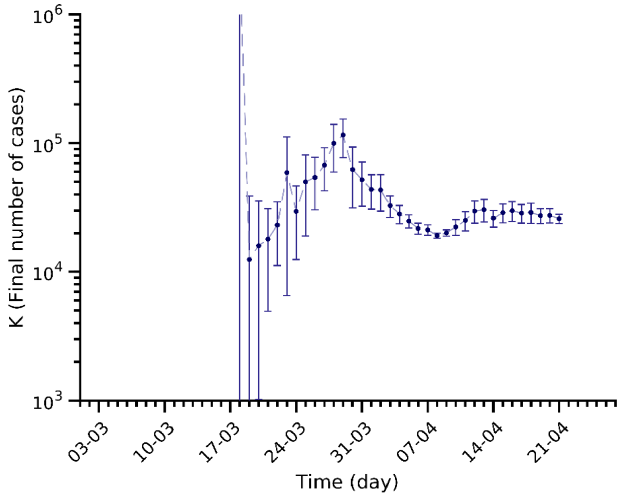


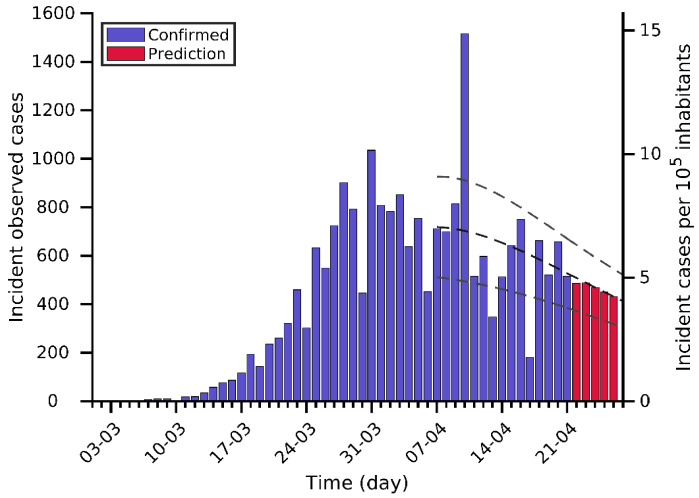
Portugal 21-04-2020. Population: 10.2M. Current cumulated incidence: 210/10⁵

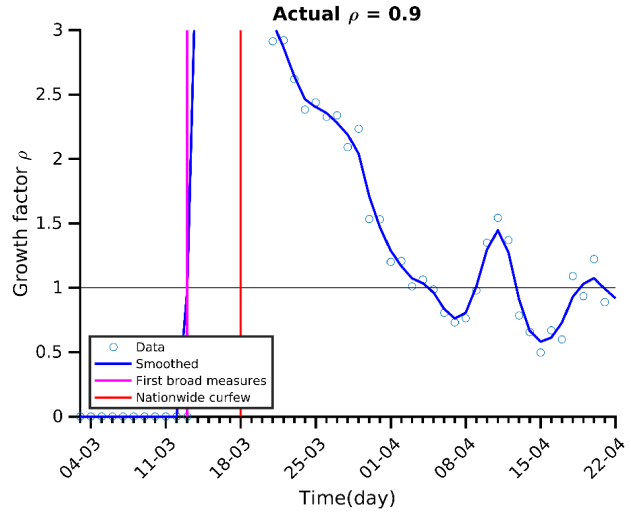


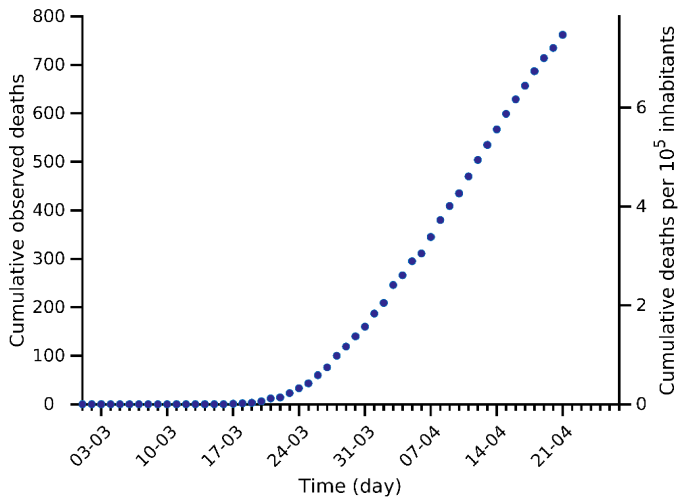


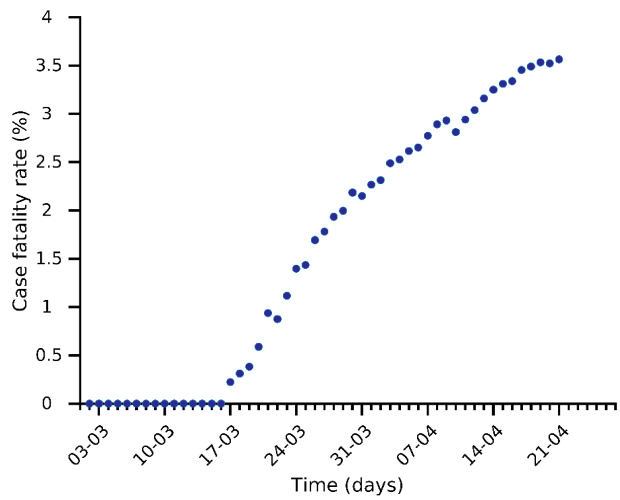




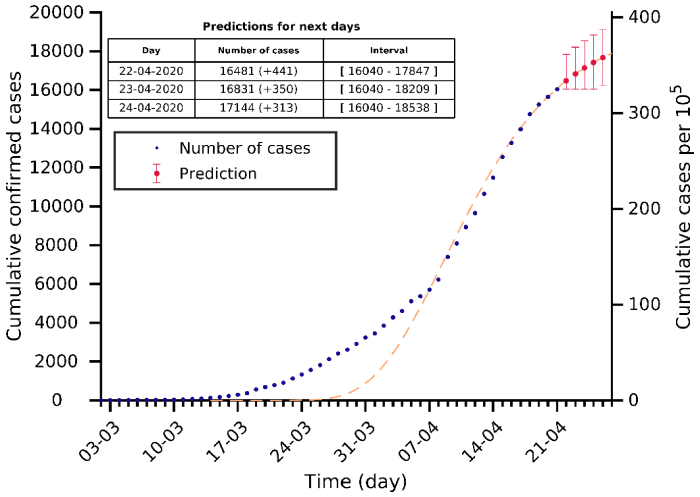


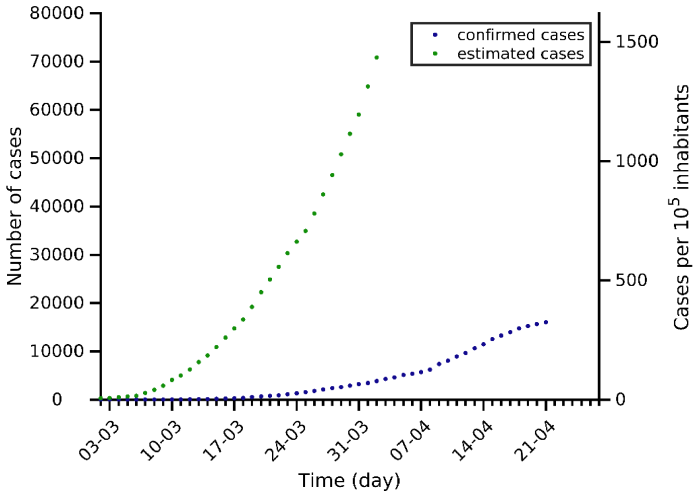


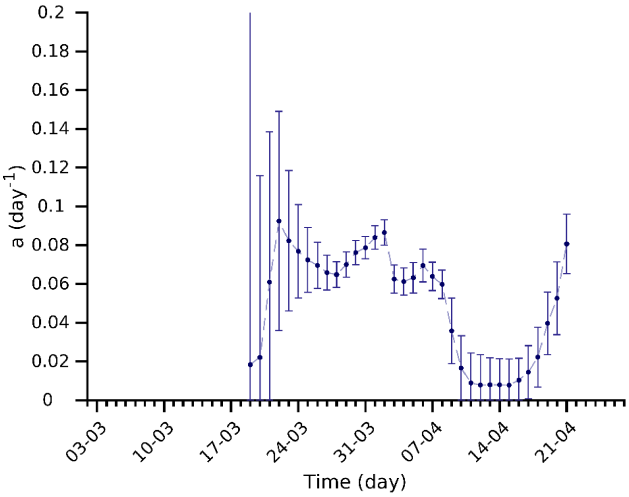


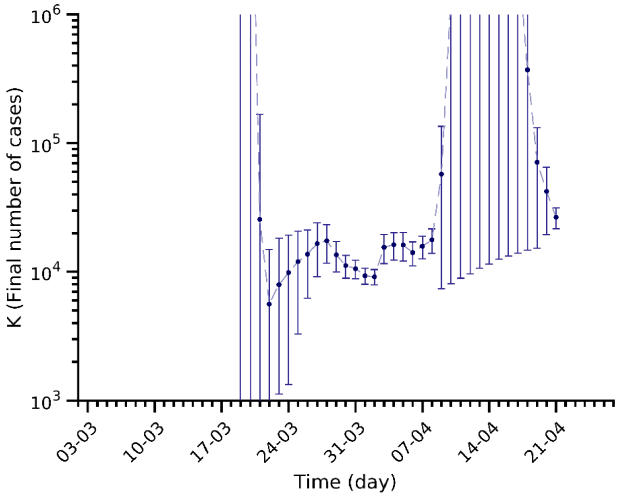


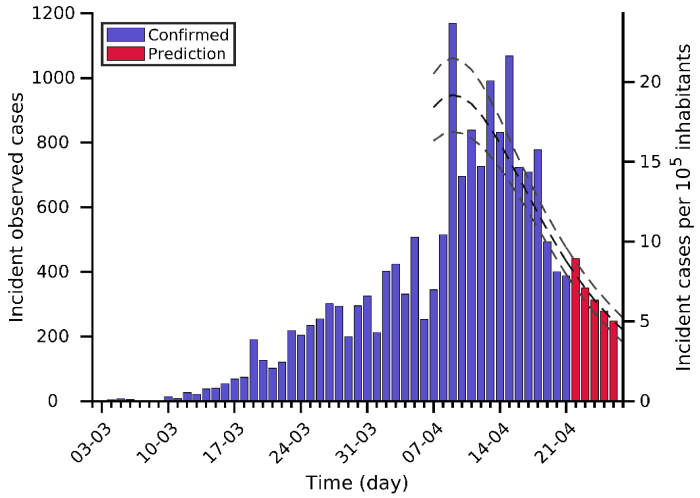
Ireland 21-04-2020. Population: 4.9M. Current cumulated incidence: 325/10⁵

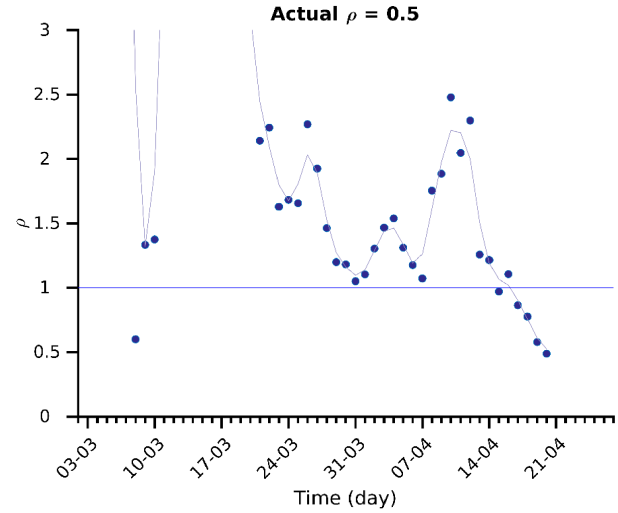


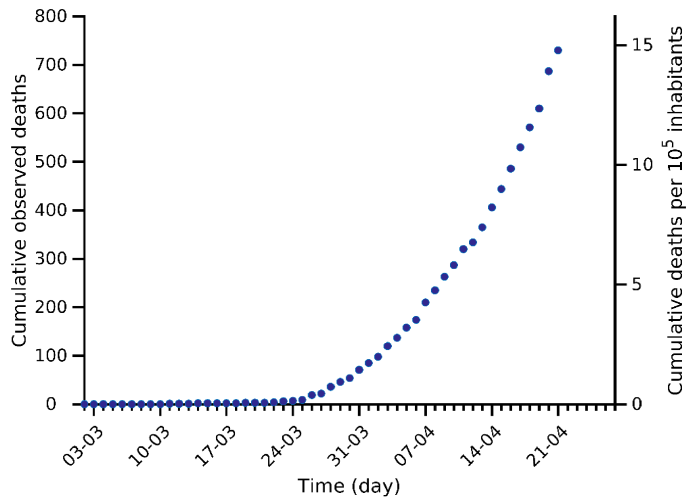


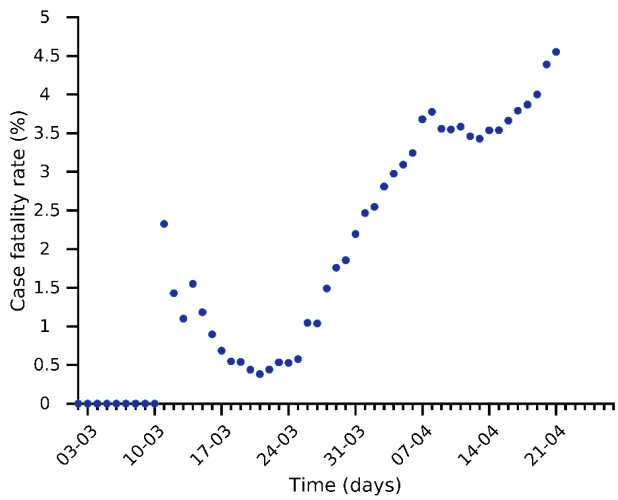




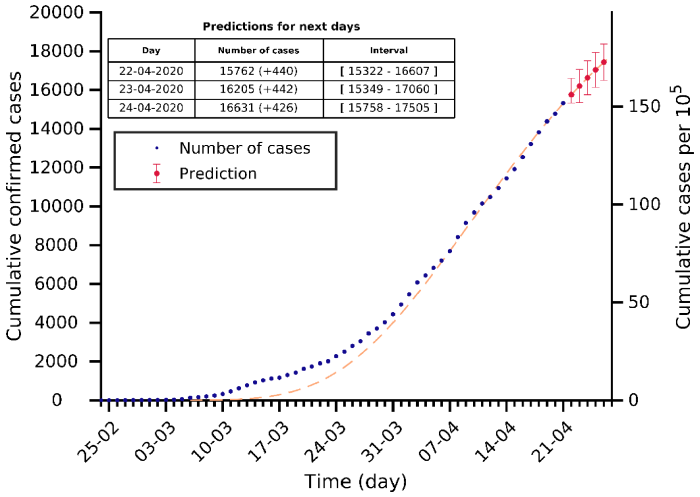


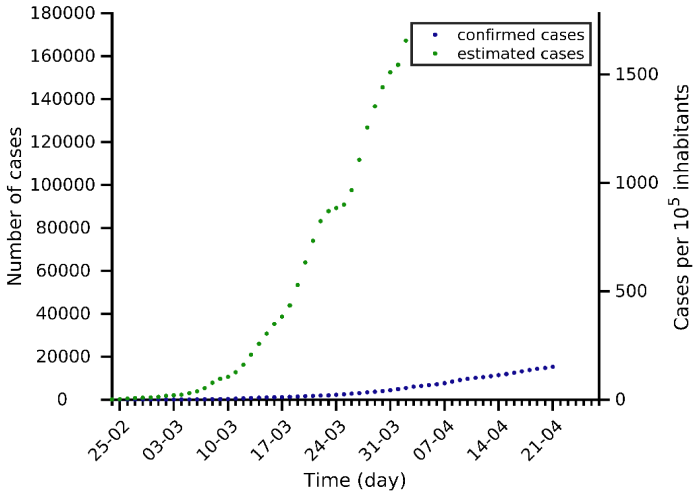


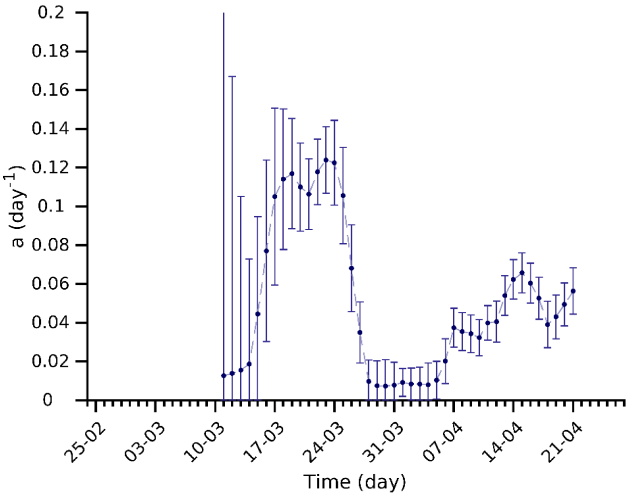


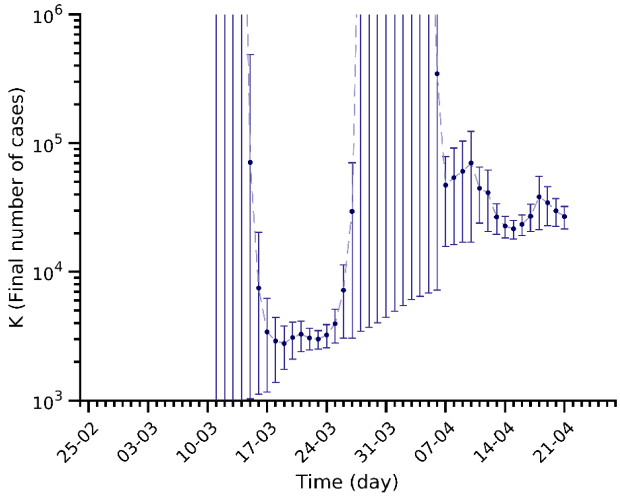


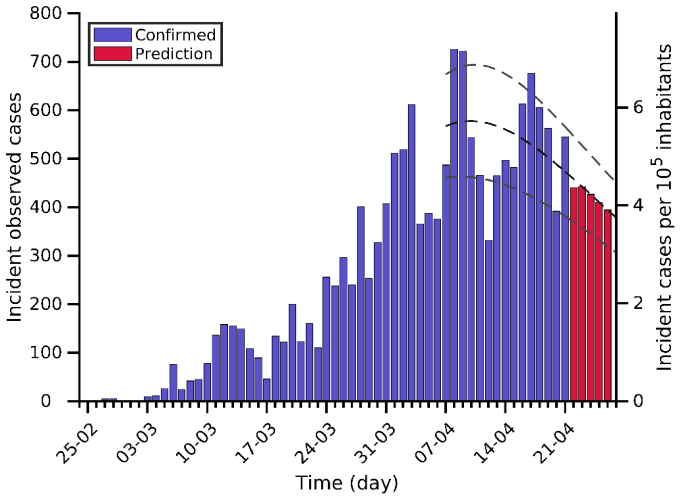
Sweden 21-04-2020. Population: 10.1M. Current cumulated incidence: 152/10⁵

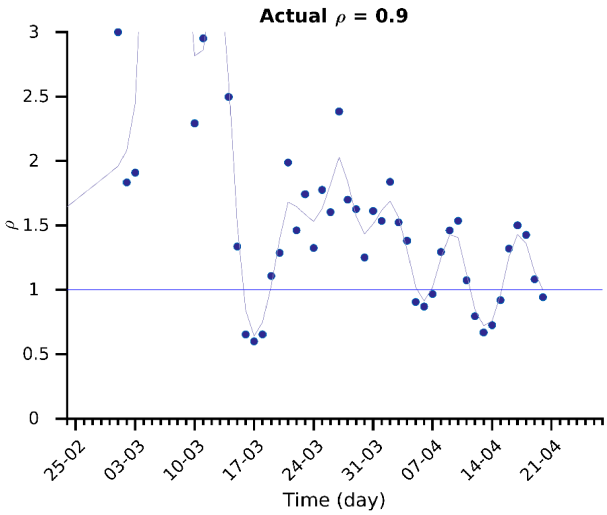


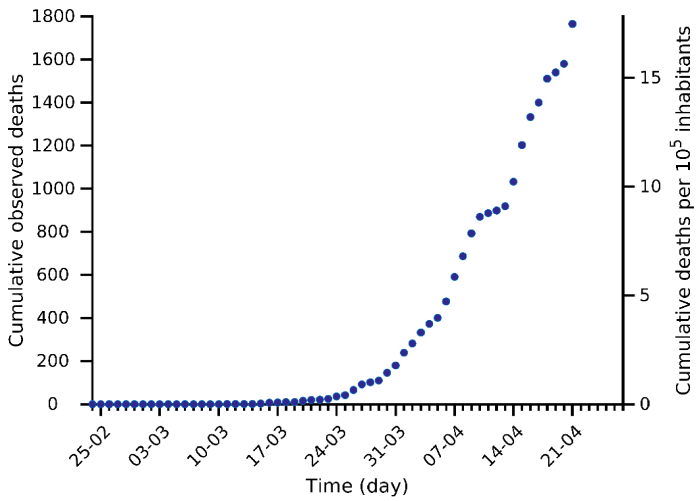


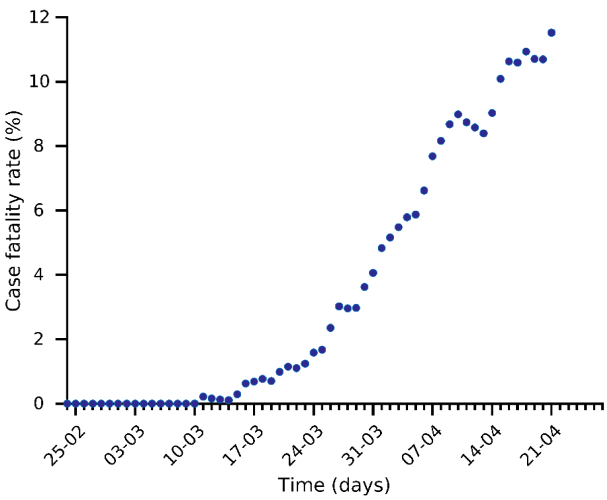




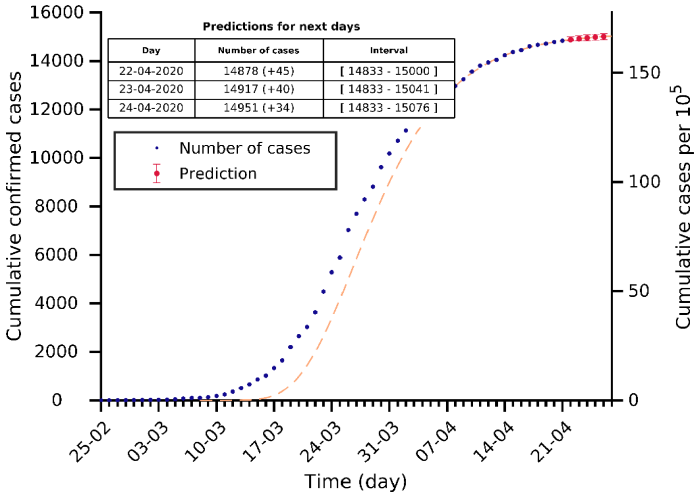


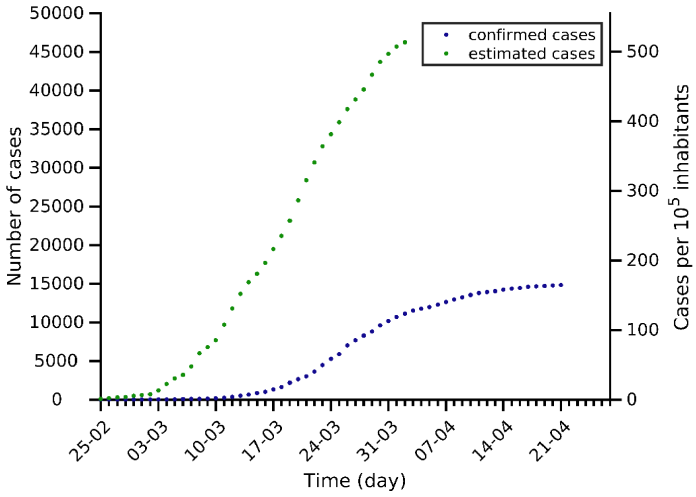


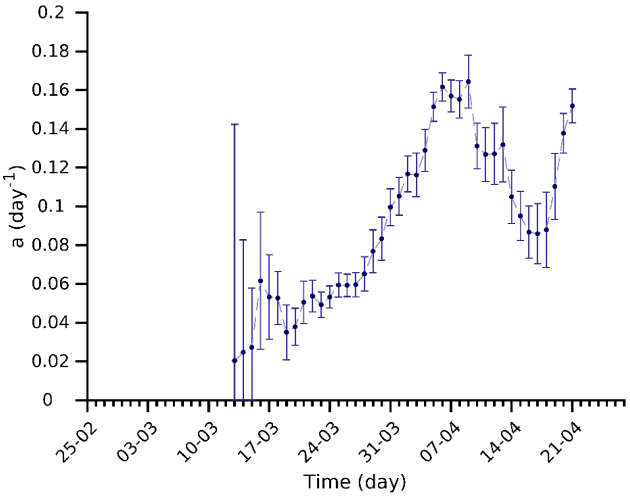


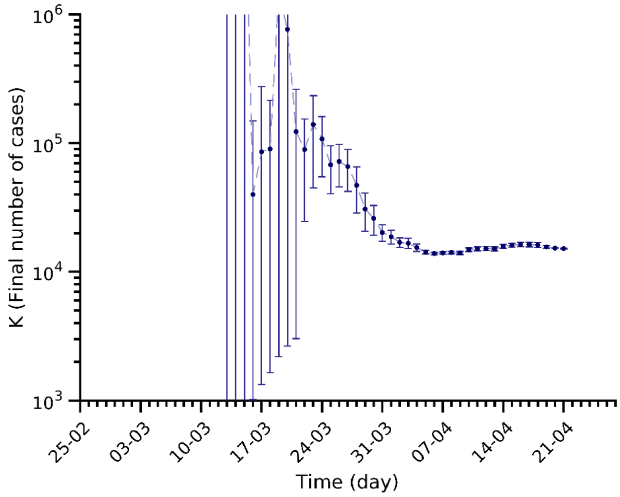


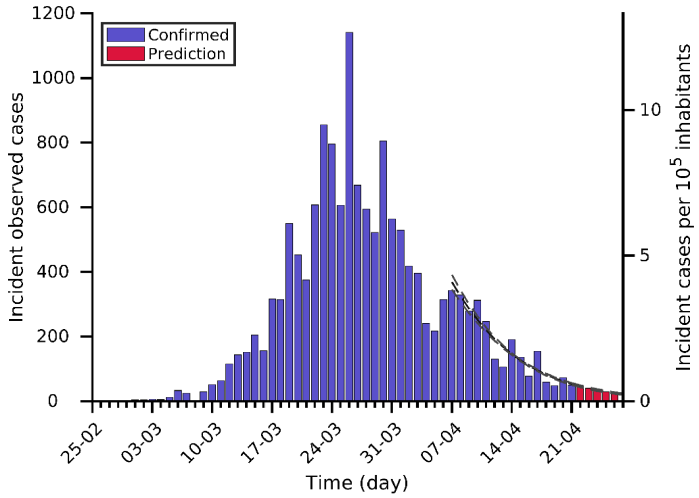
Austria 21-04-2020. Population: 9.0M. Current cumulated incidence: 165/10⁵

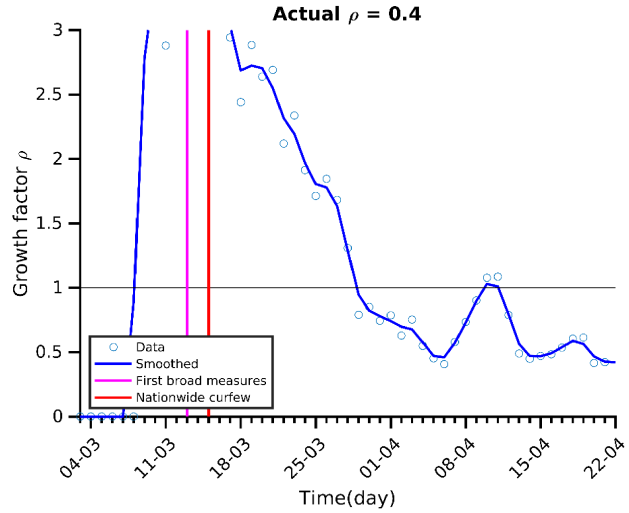


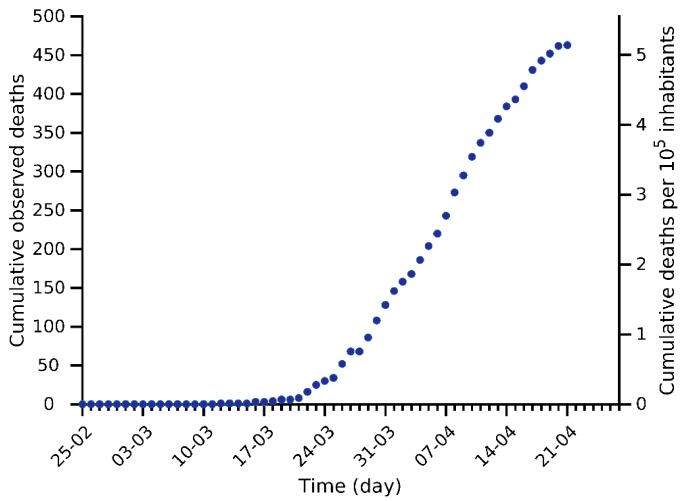


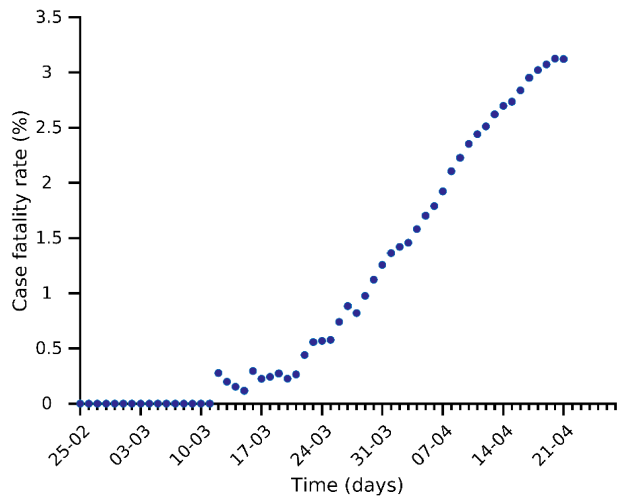




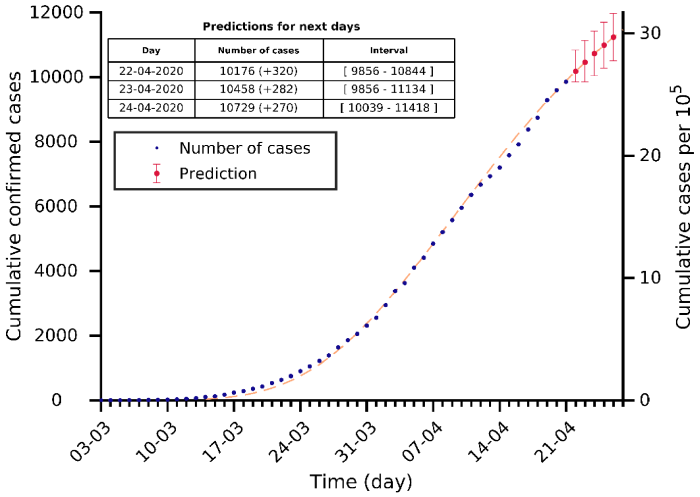


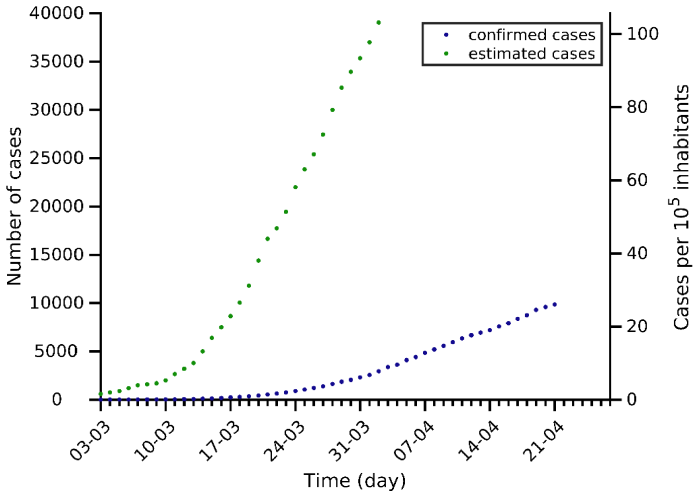


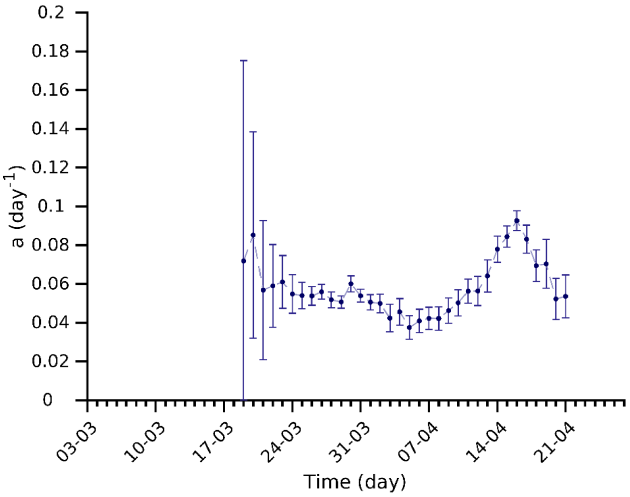


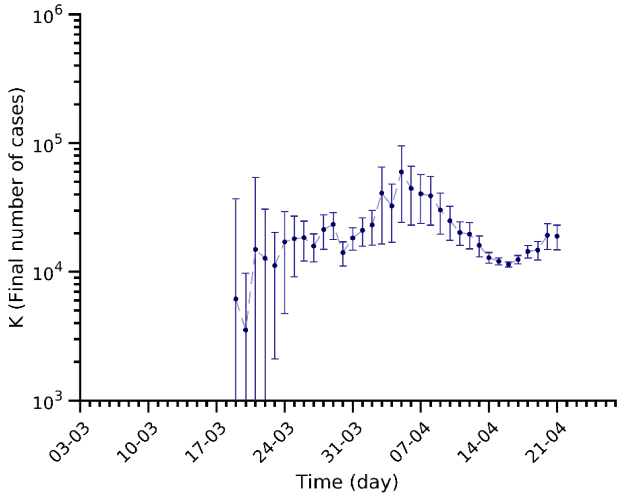


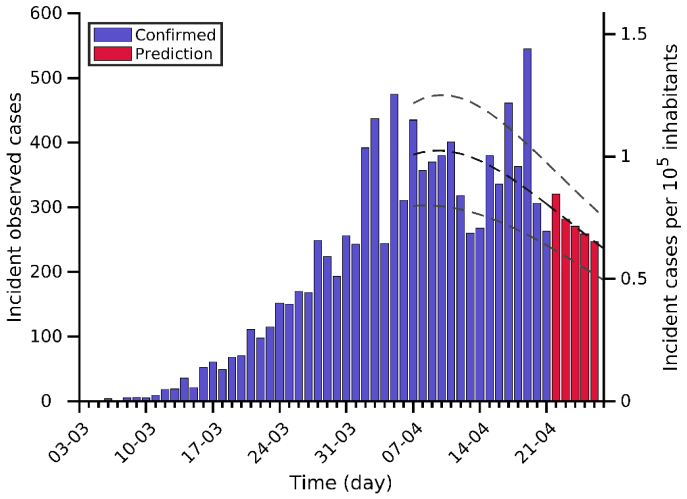
Poland 21-04-2020. Population: 37.8M. Current cumulated incidence: 26/10^5

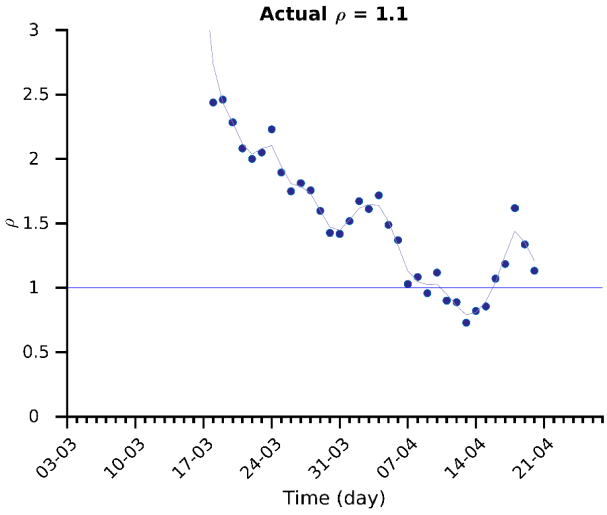


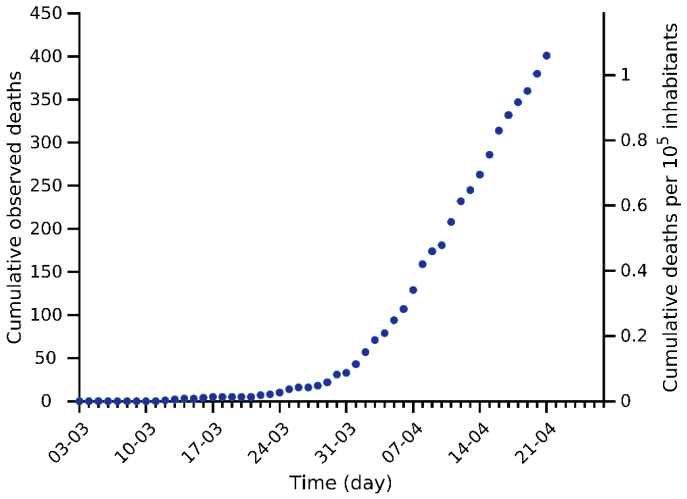


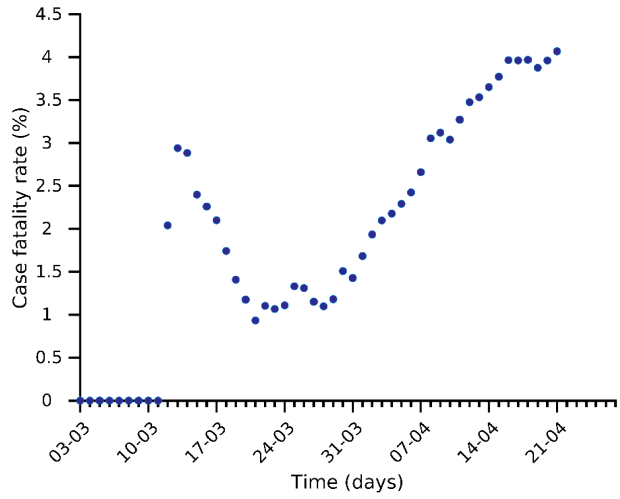




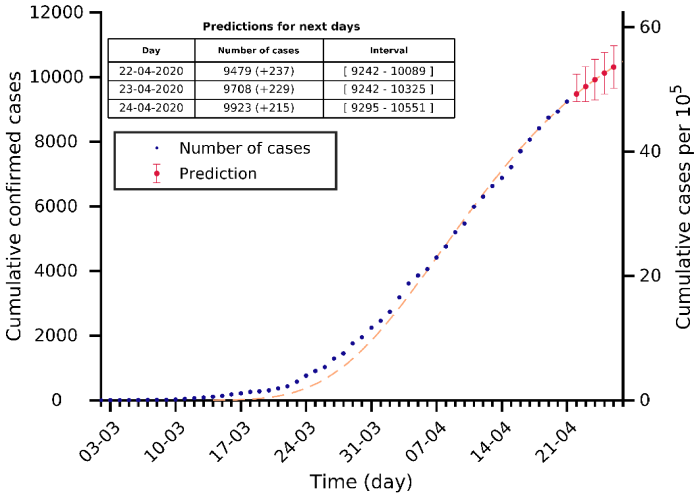


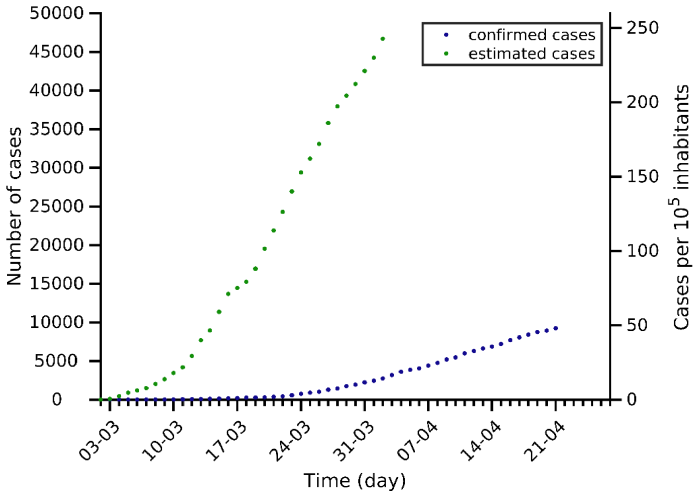


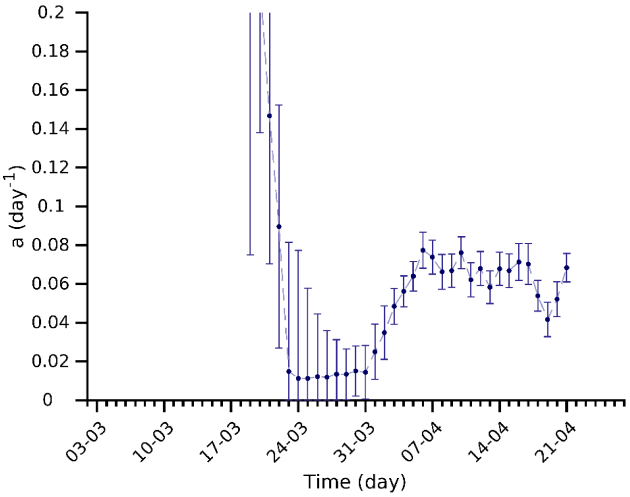


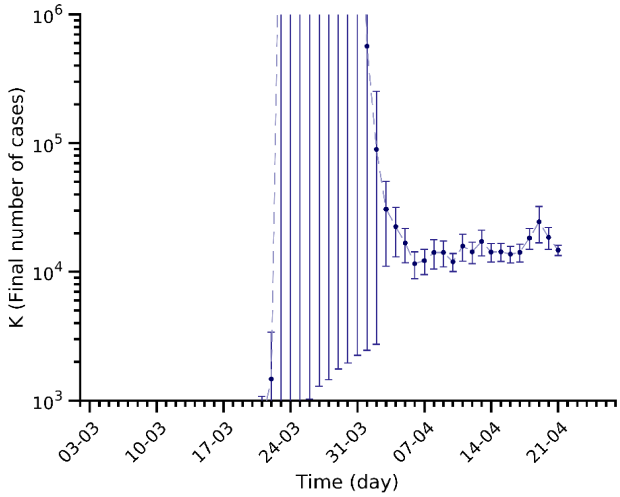


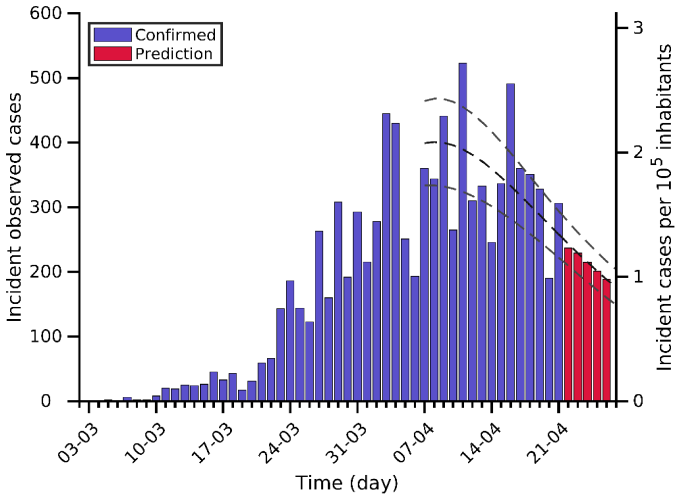
Romania 21-04-2020. Population: 19.2M. Current cumulated incidence: 48/10^5

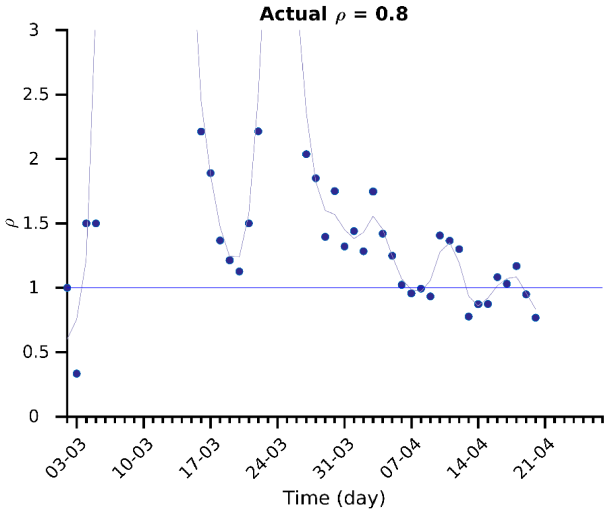


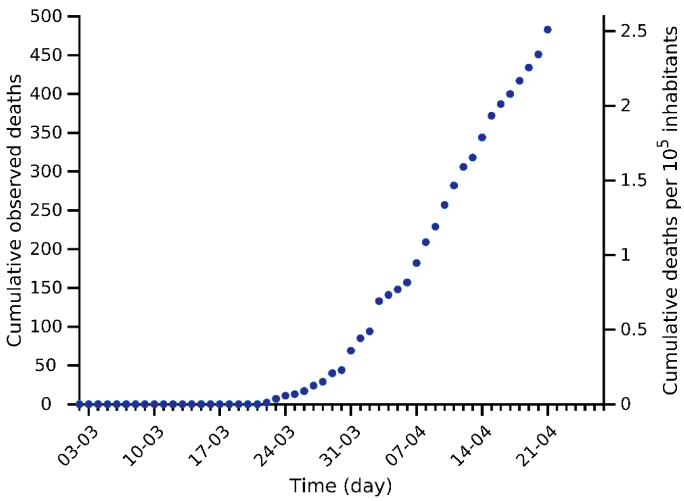


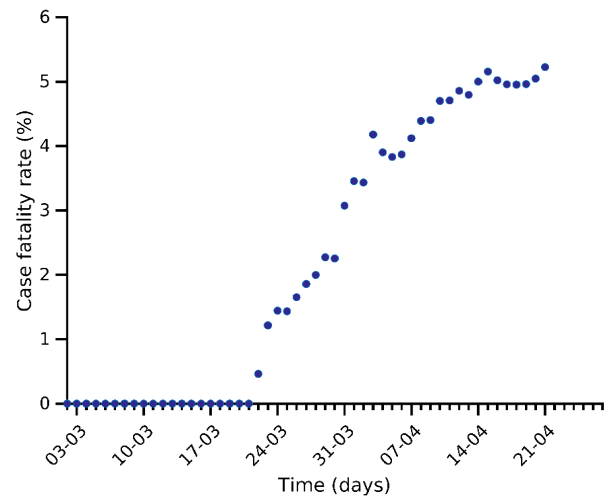




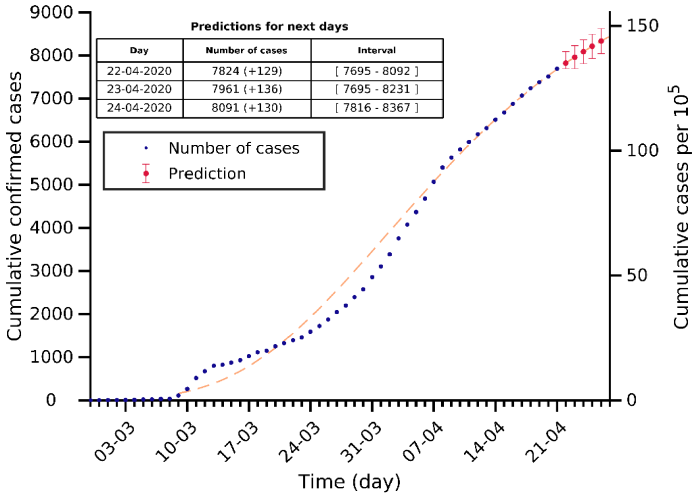


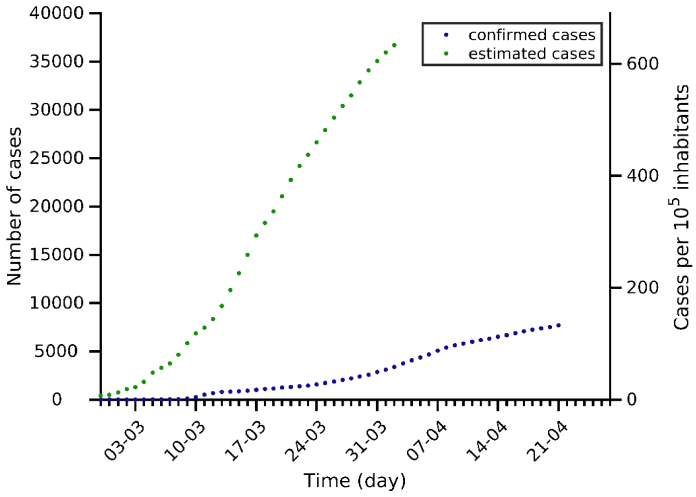


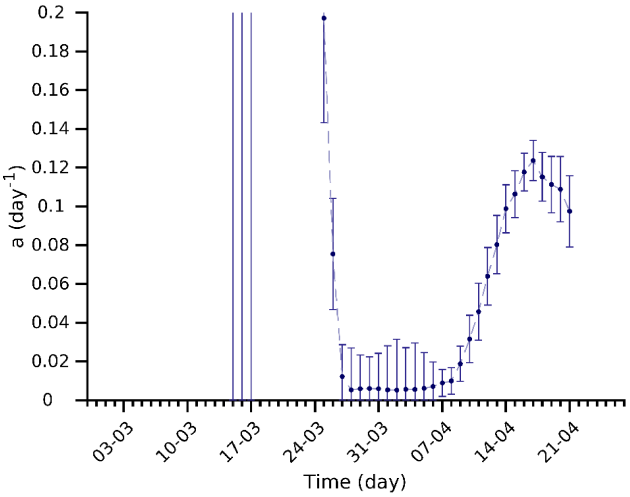


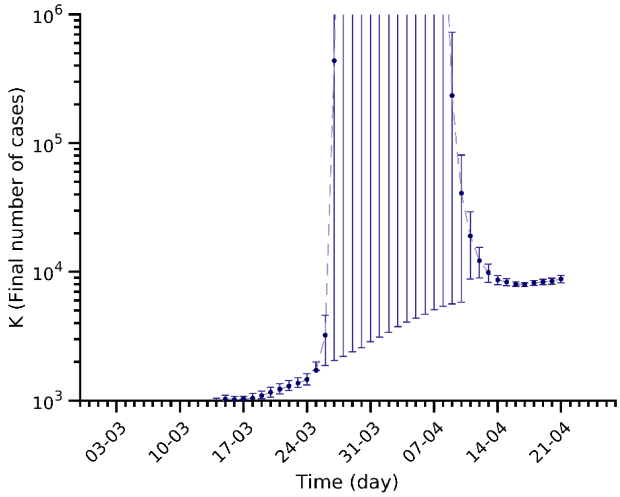


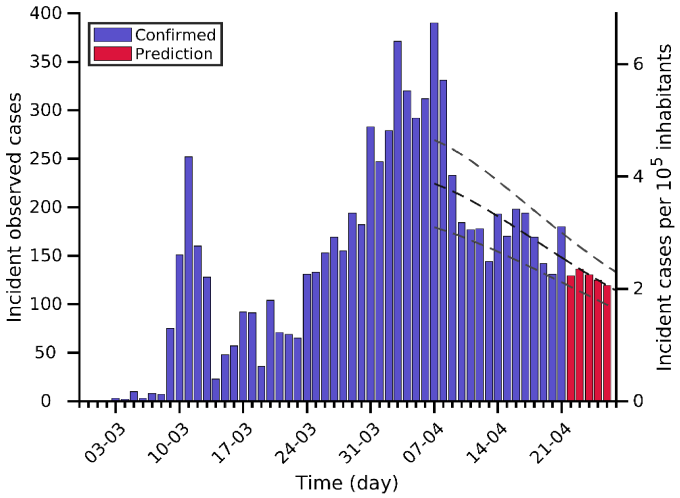
Denmark 21-04-2020. Population: 5.8M. Current cumulated incidence: 133/10⁵

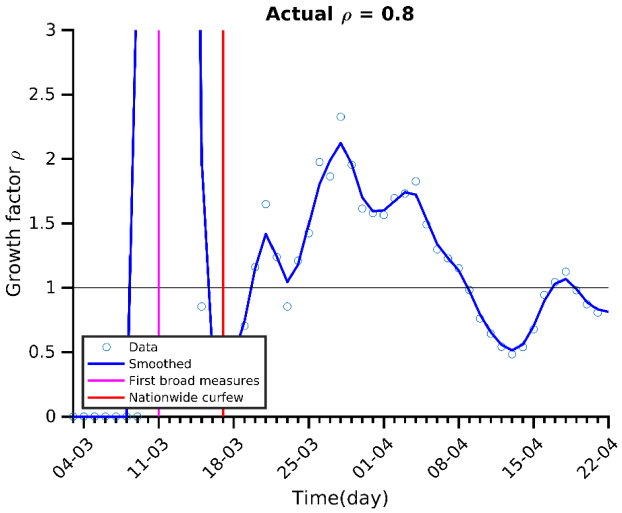


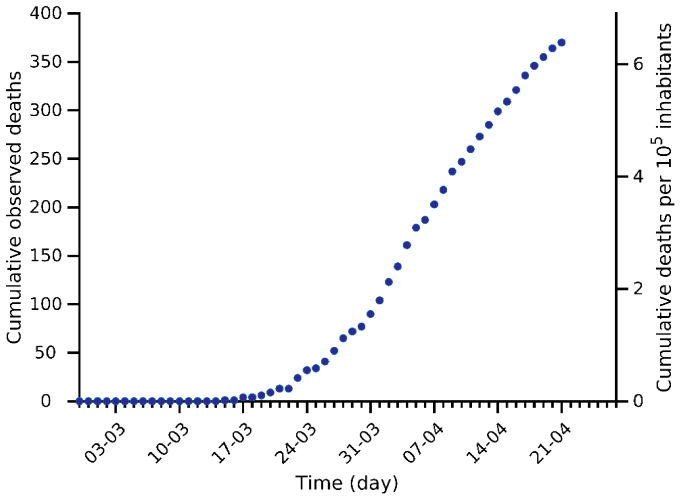


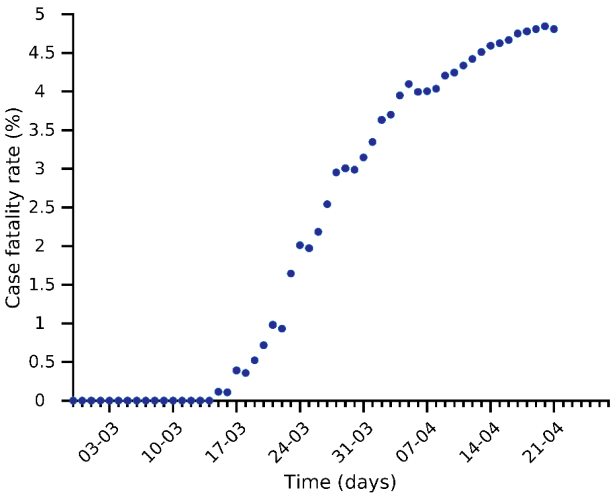




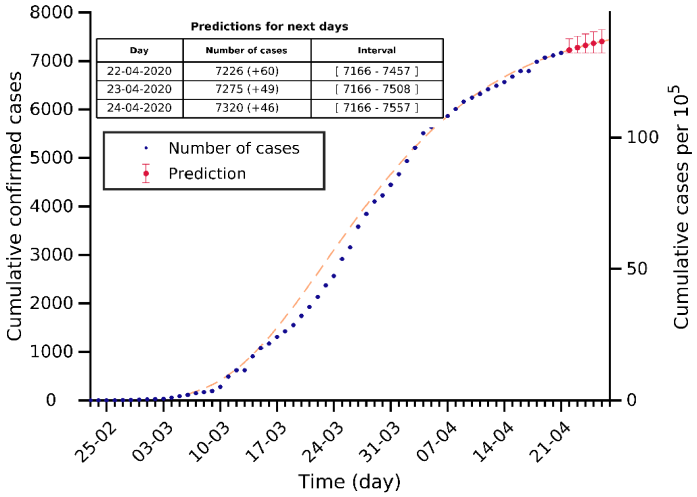


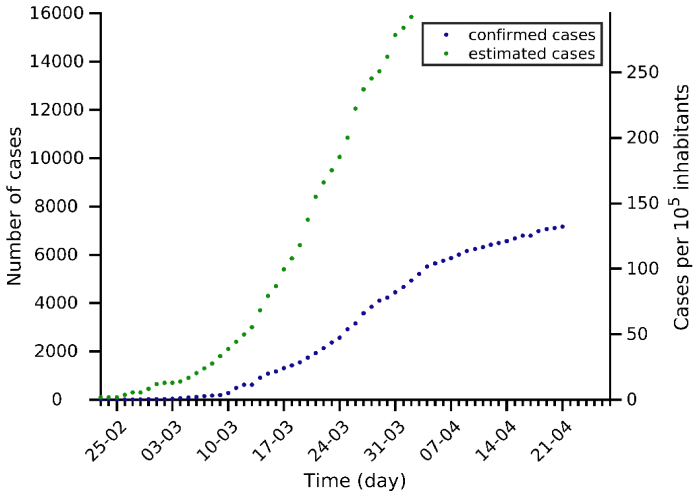


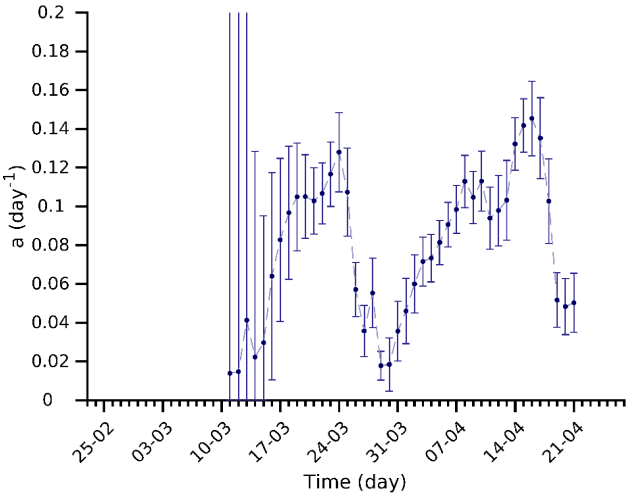


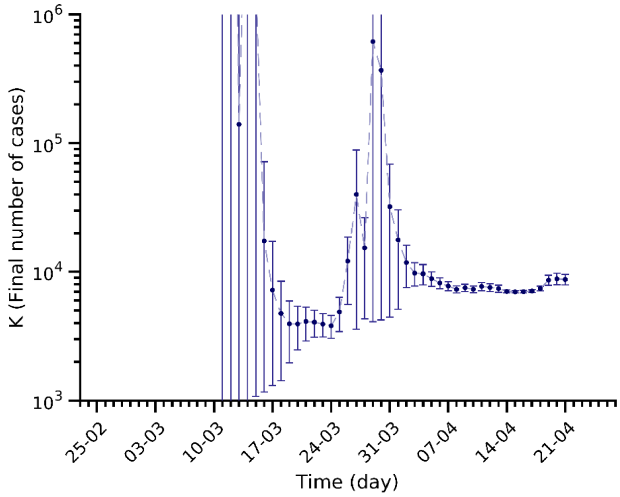


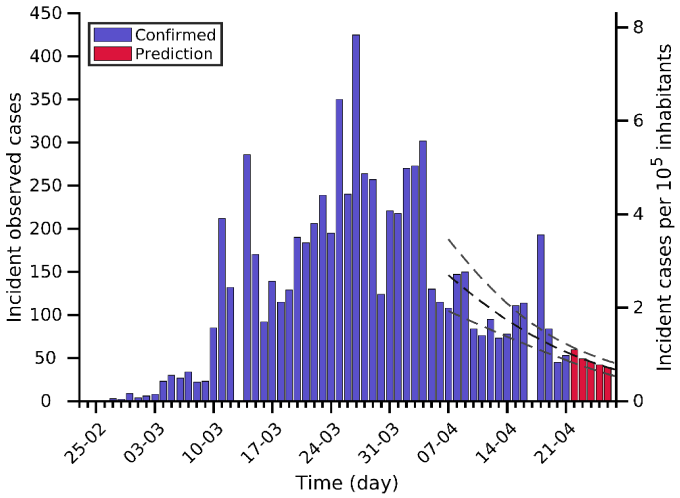
Norway 21-04-2020. Population: 5.4M. Current cumulated incidence: 132/10^5

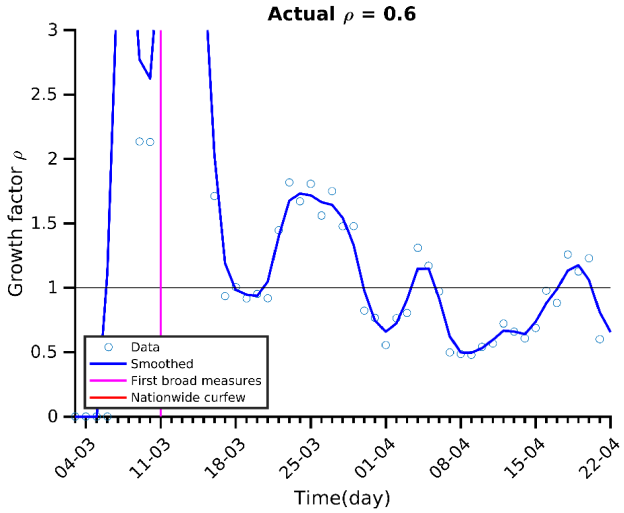


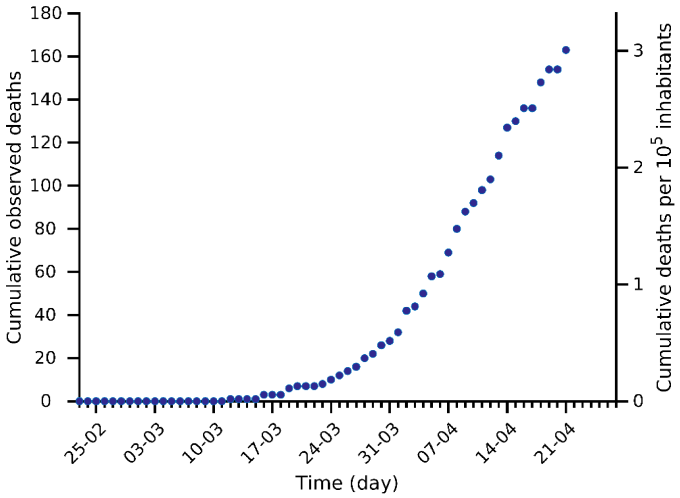


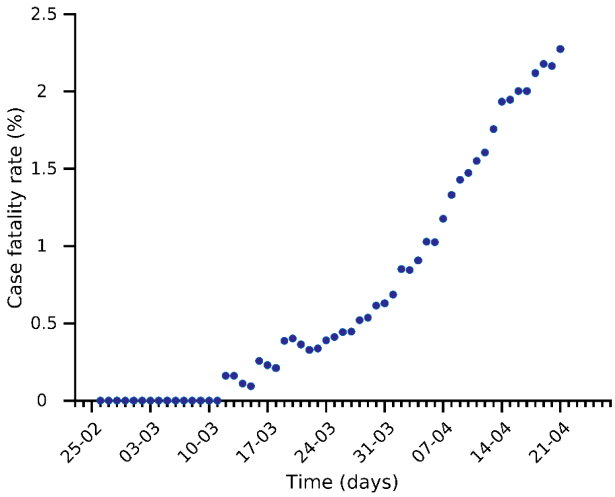




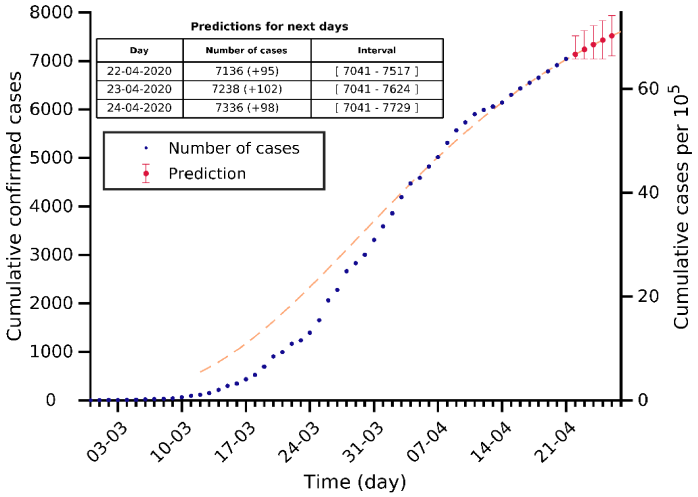


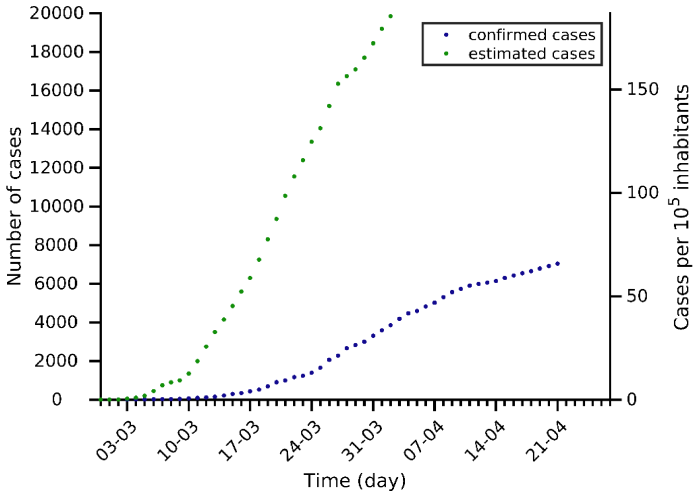


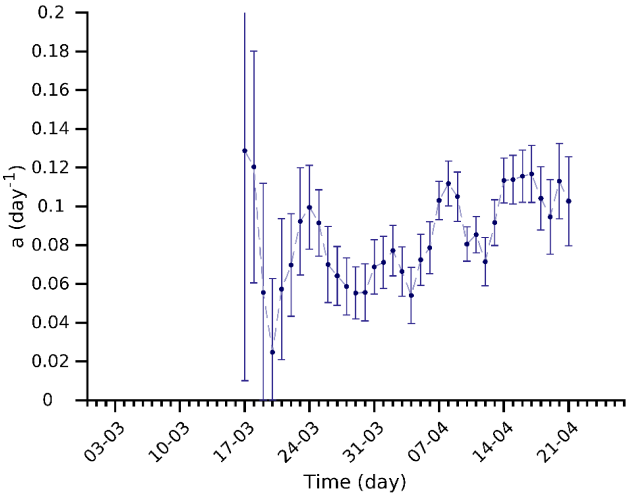


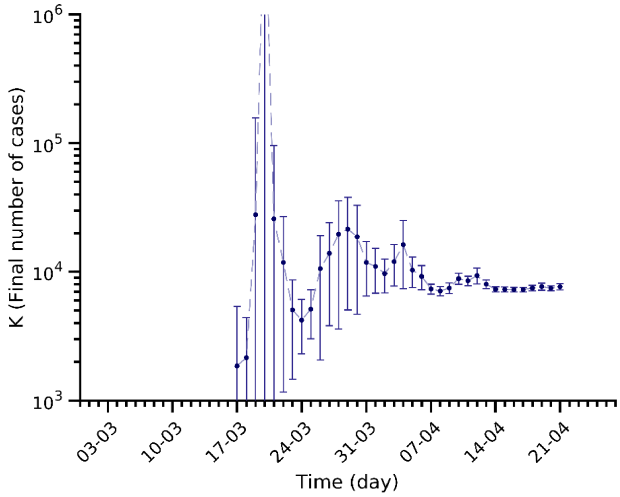


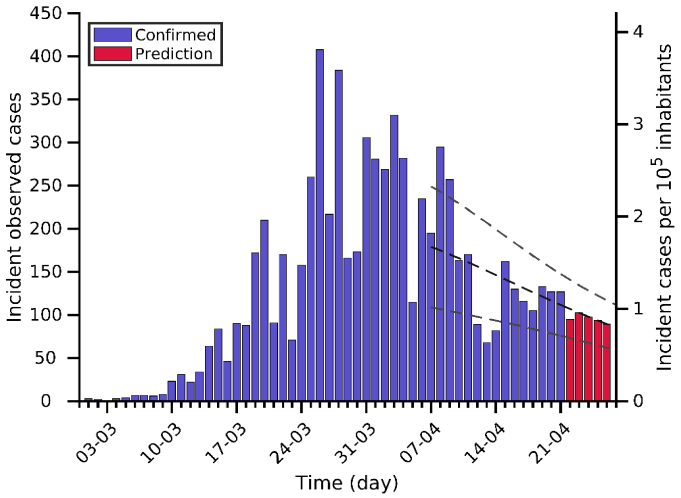
Czech Rep 21-04-2020. Population: 10.7M. Current cumulated incidence: 66/10^5

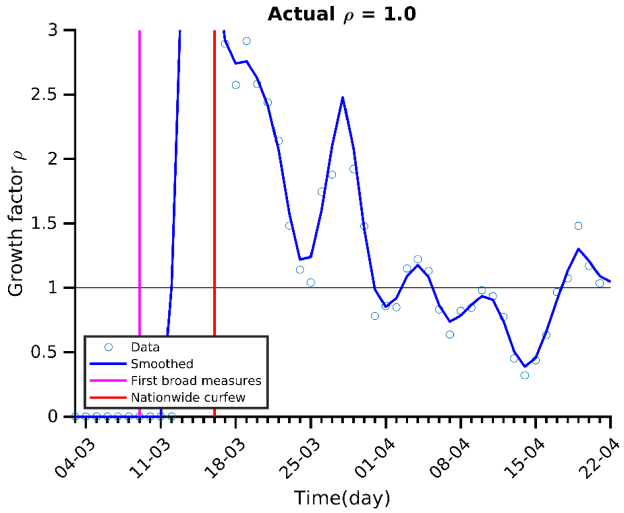


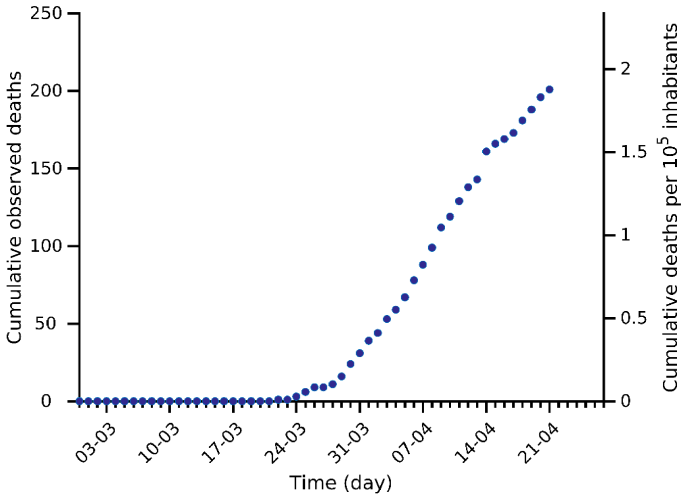


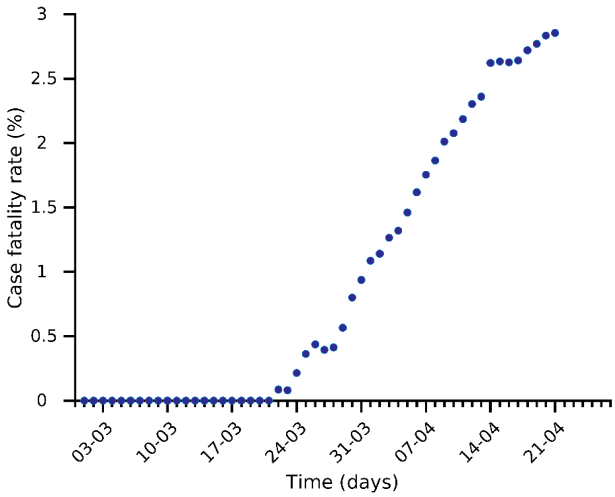




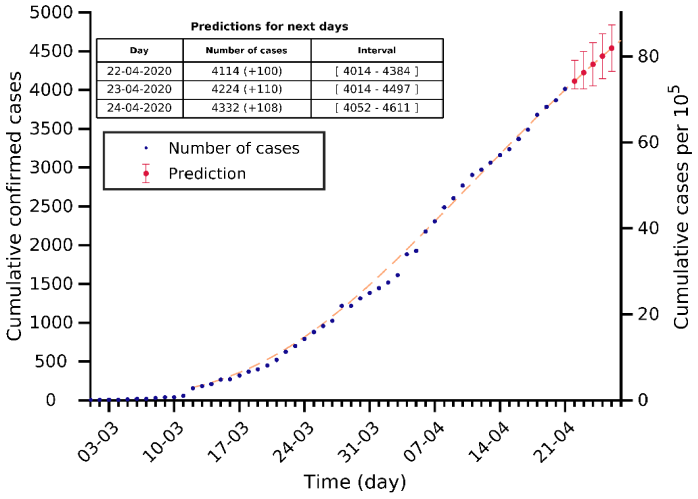


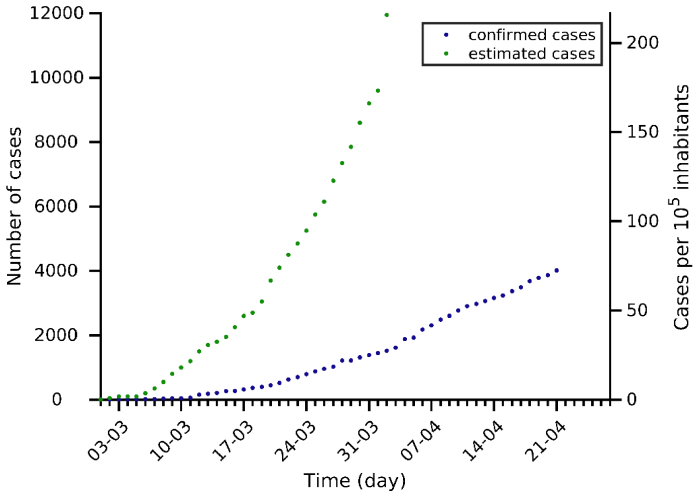


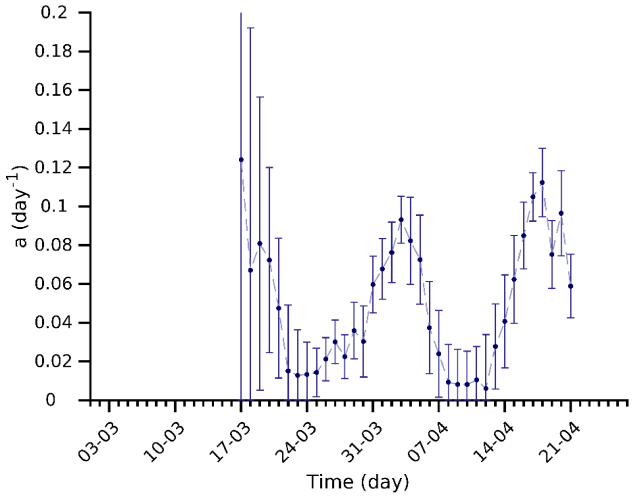


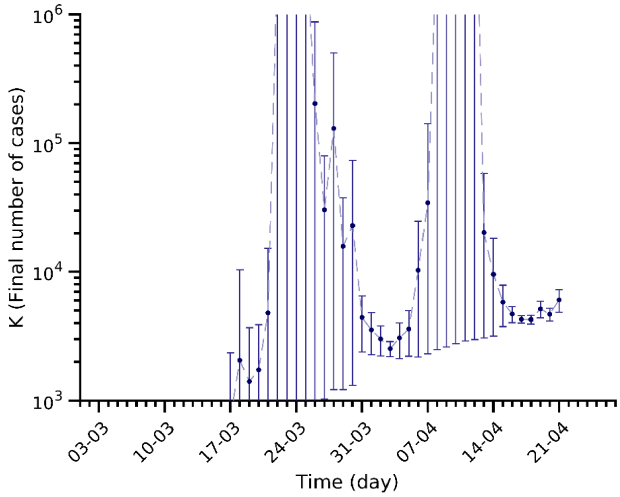


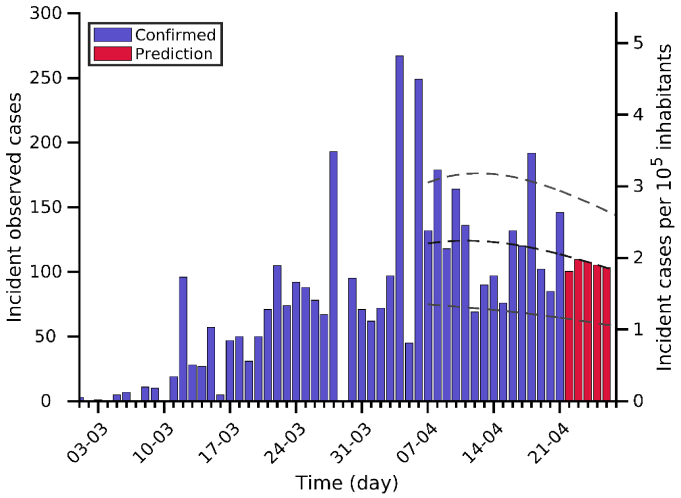
Finland 21-04-2020. Population: 5.5M. Current cumulated incidence: 72/10^5

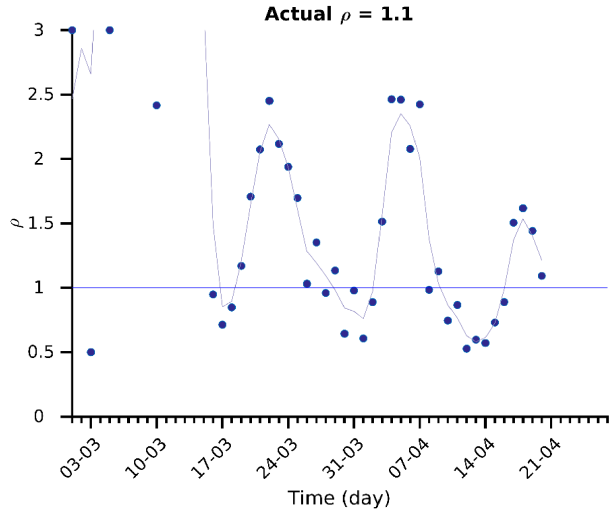


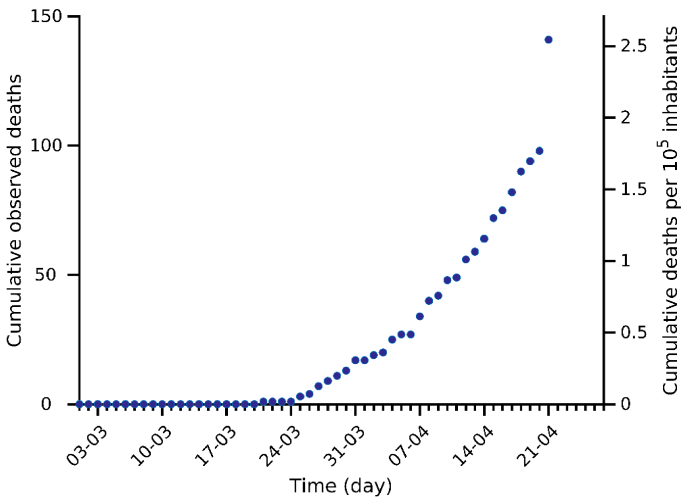


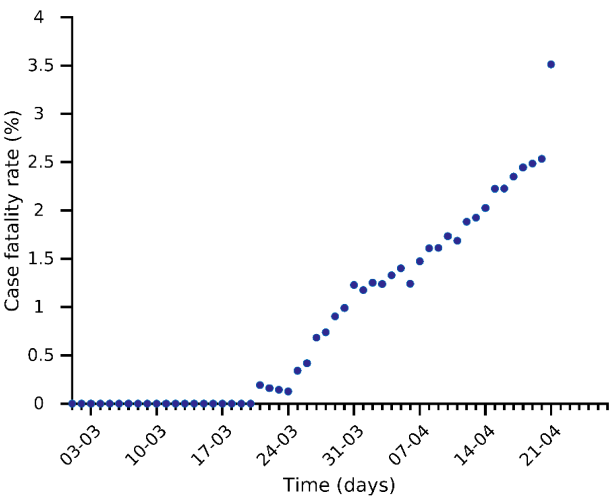




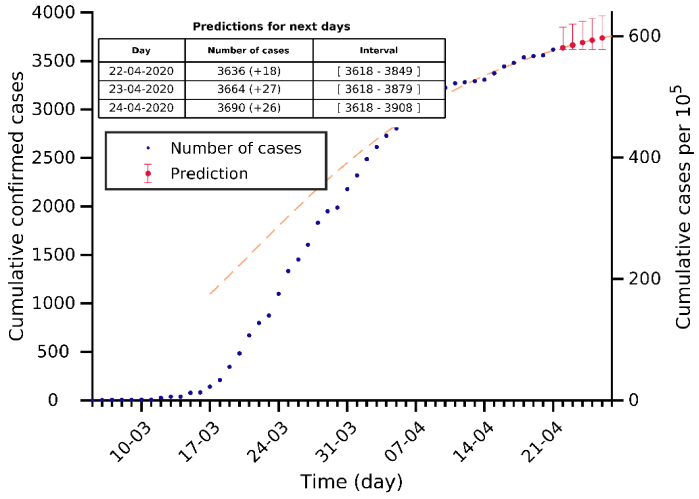


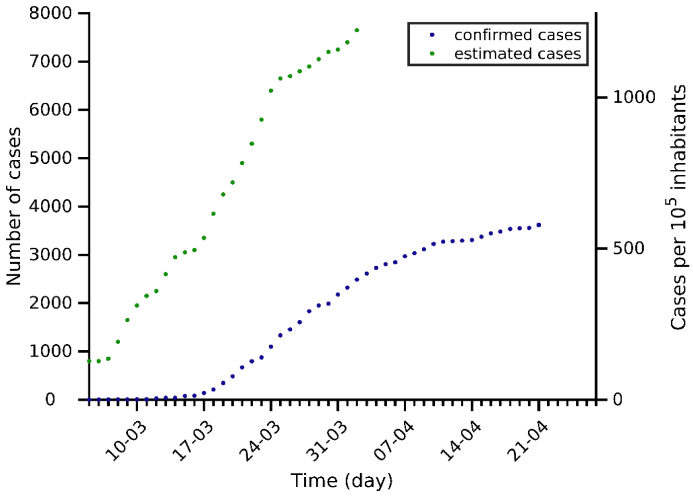


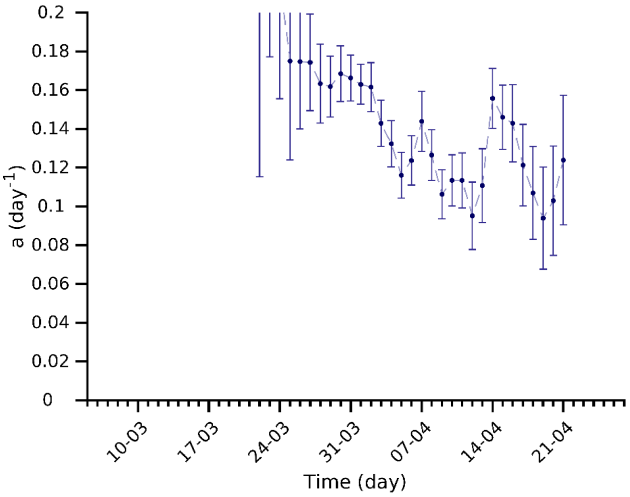


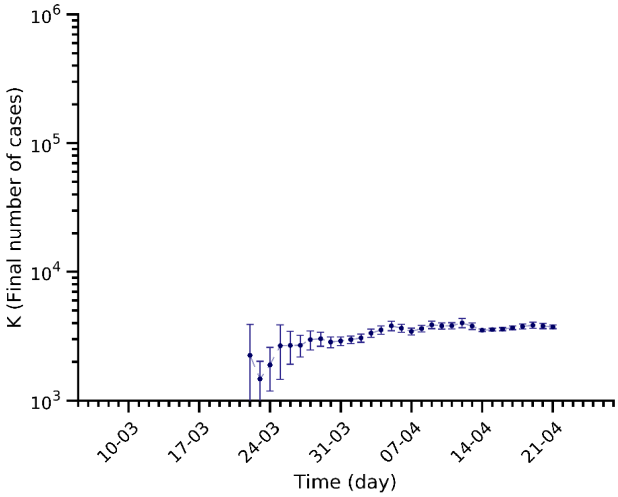


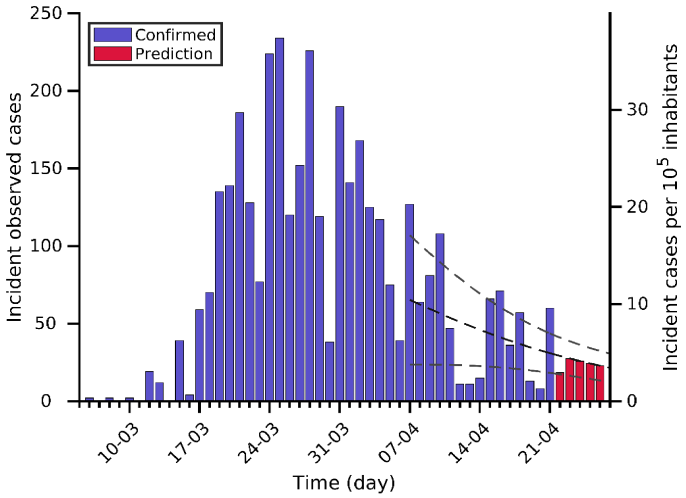
Luxembourg 21-04-2020. Population: 0.6M. Current cumulated incidence: 578/10^5

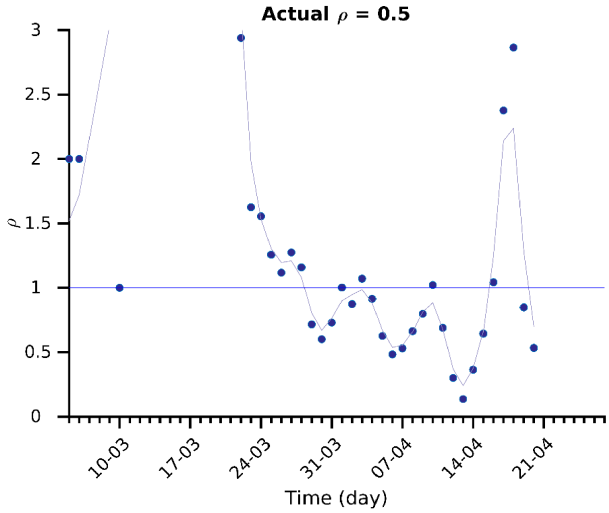


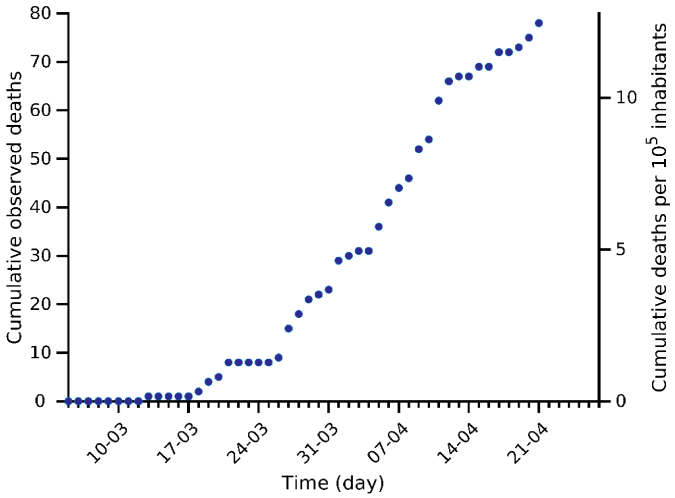


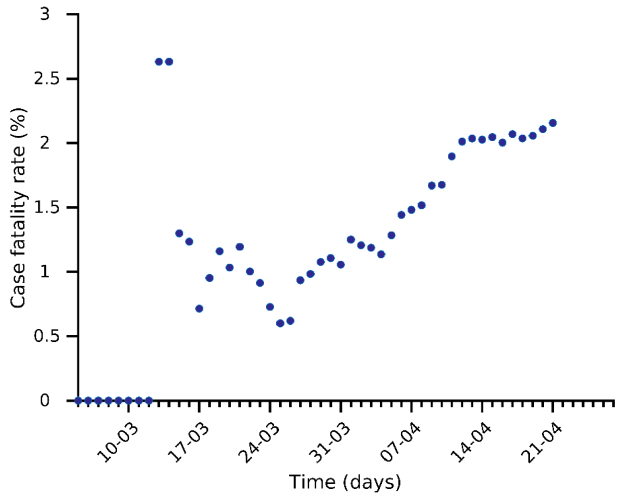




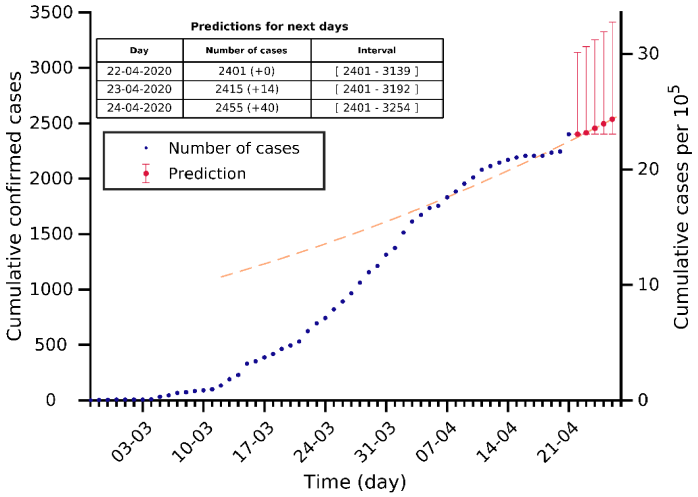


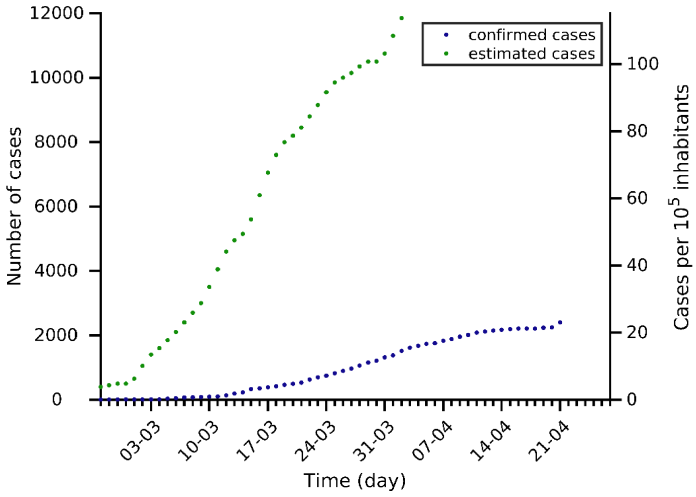


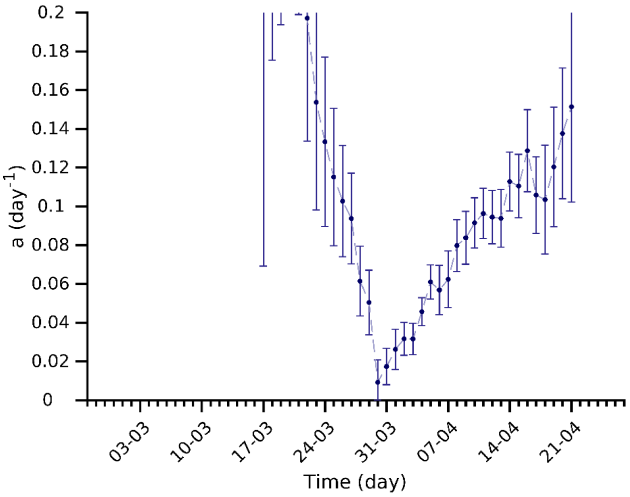


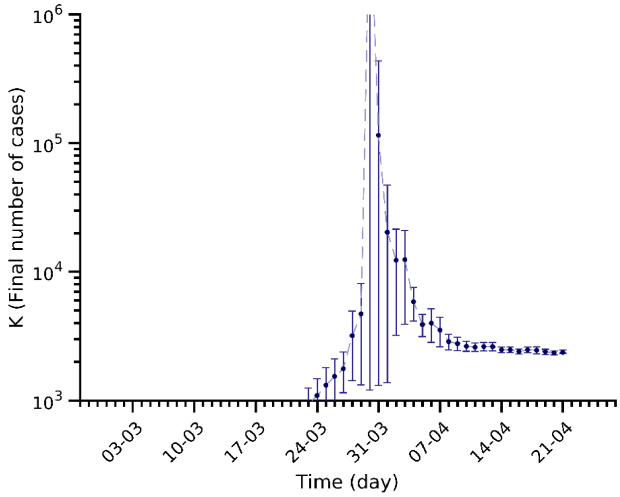


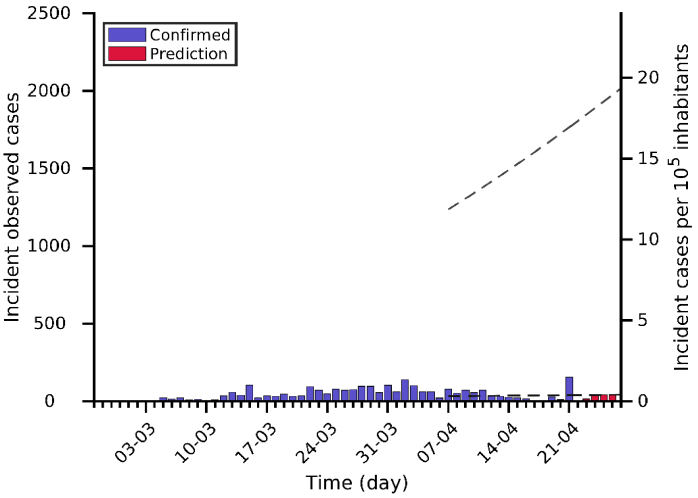
Greece 21-04-2020. Population: 10.4M. Current cumulated incidence: $23/10^5$

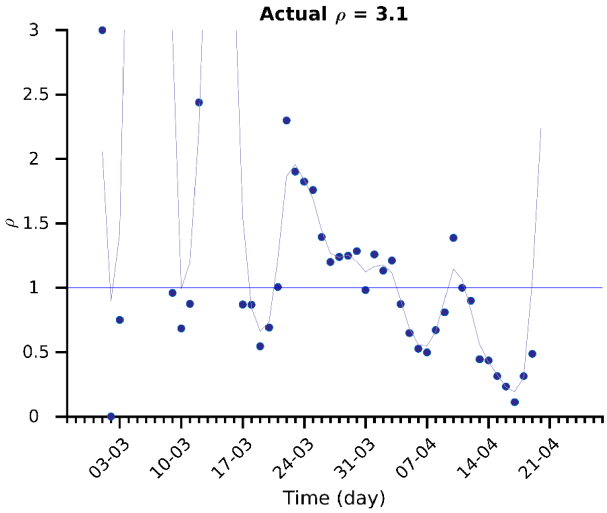


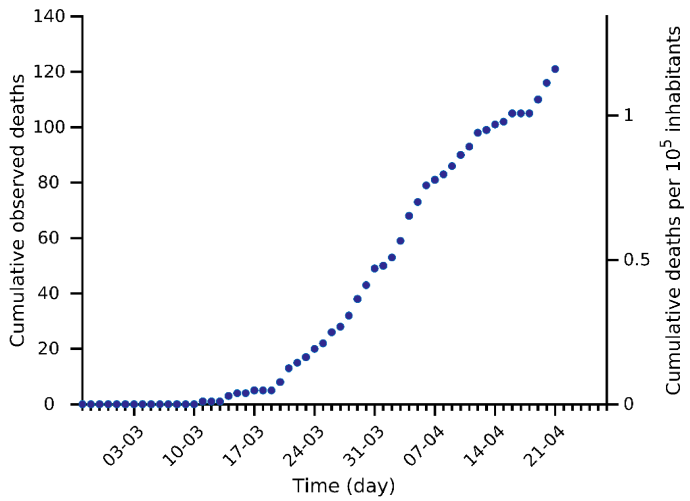


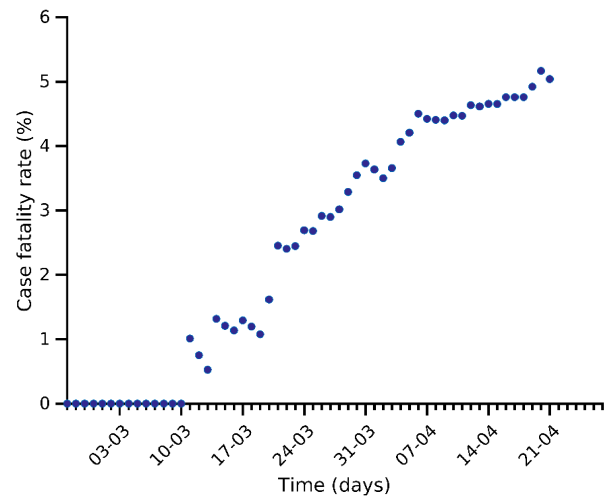




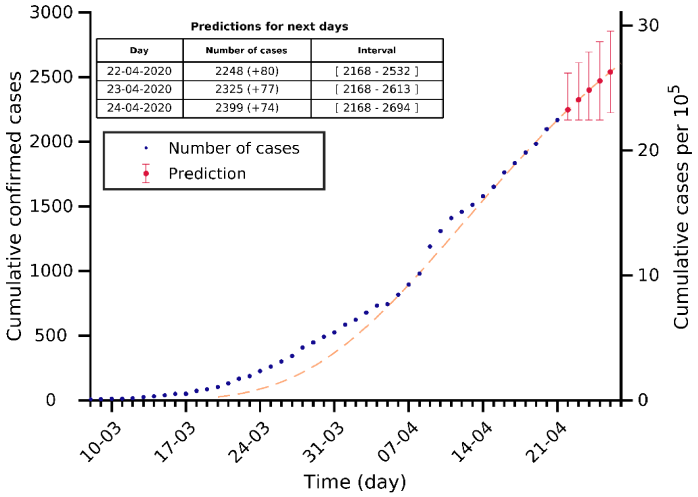


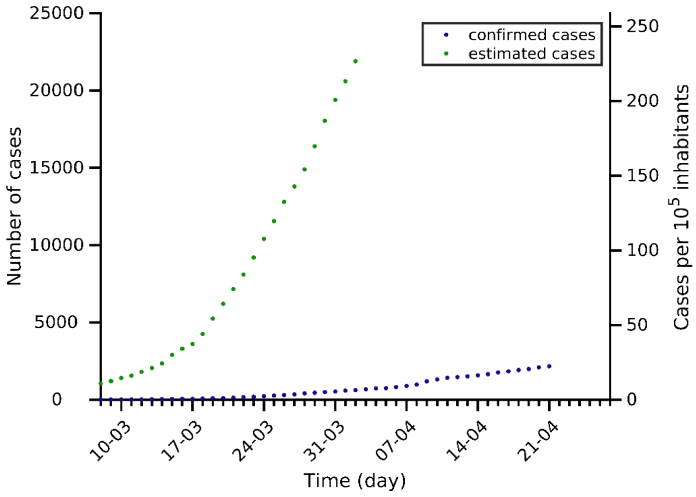


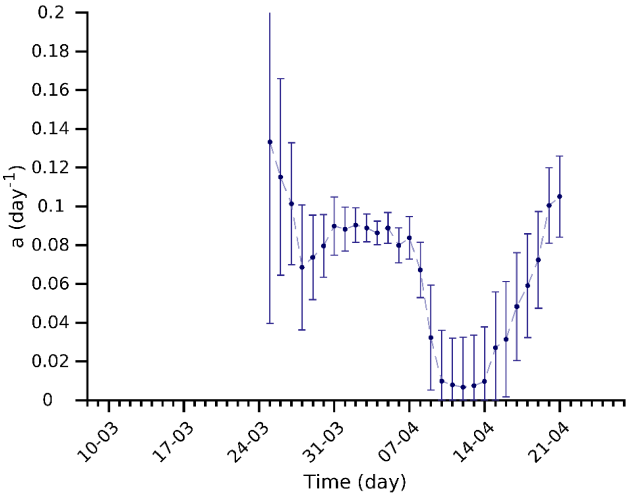


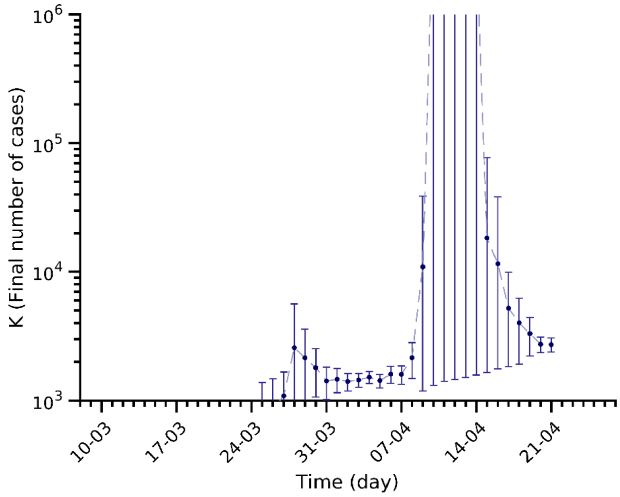


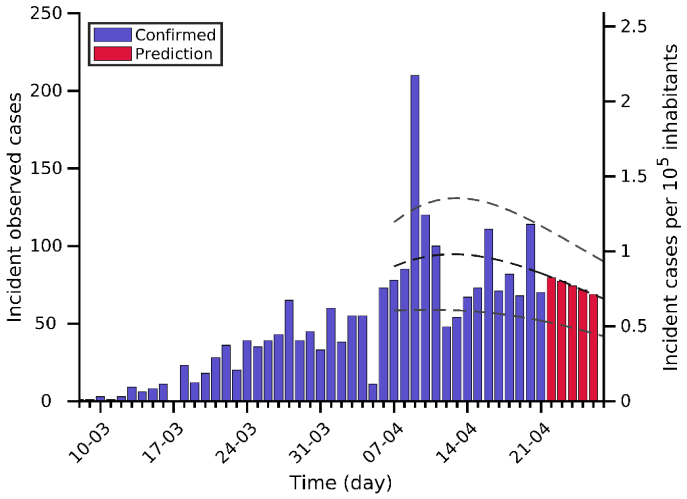
Hungary 21-04-2020. Population: 9.7M. Current cumulated incidence: 22/10^5

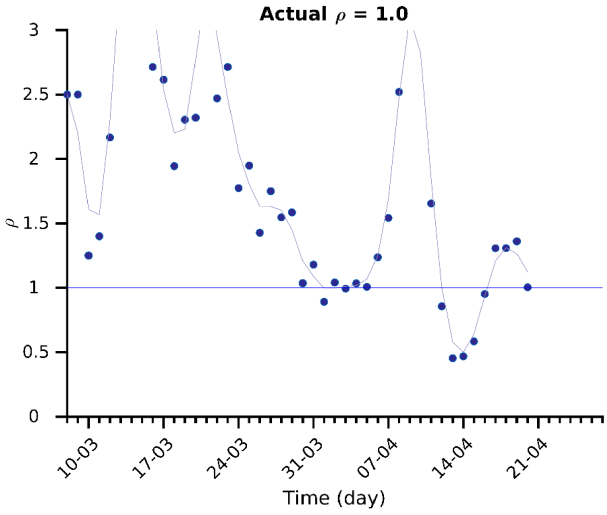


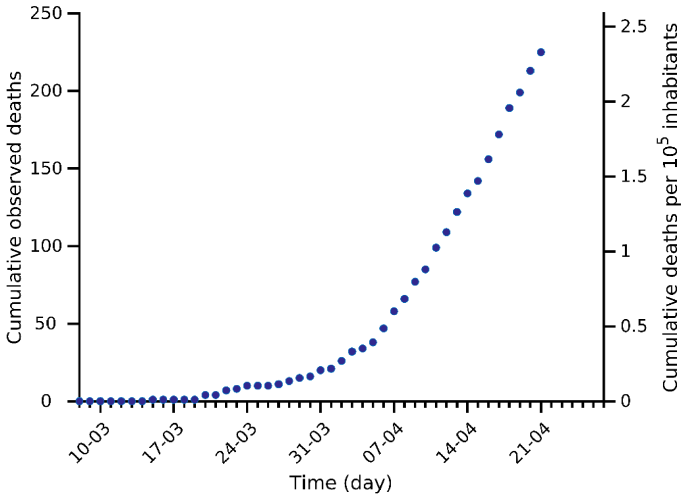


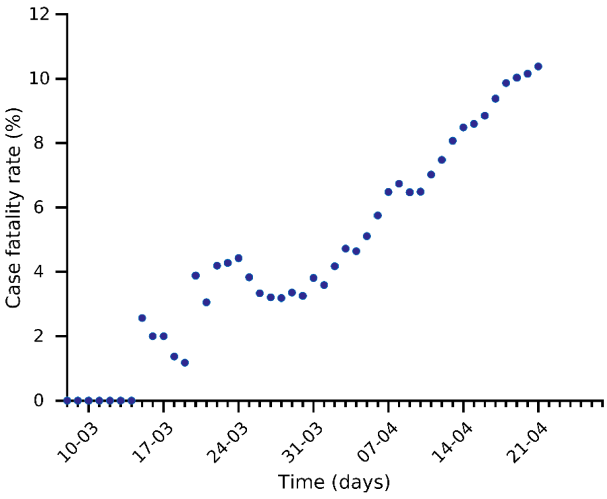




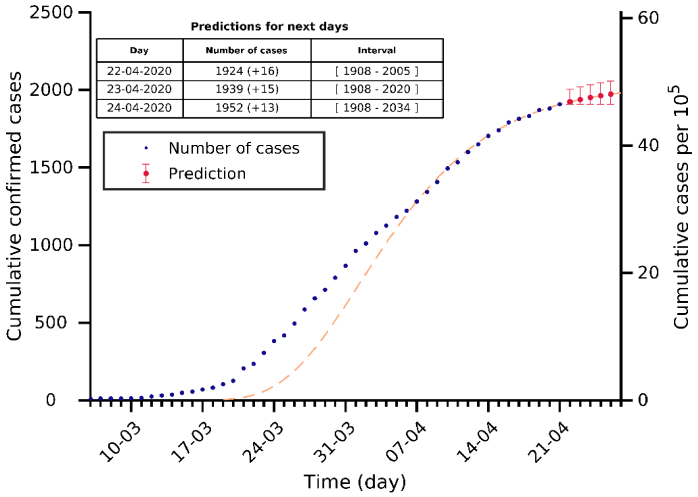


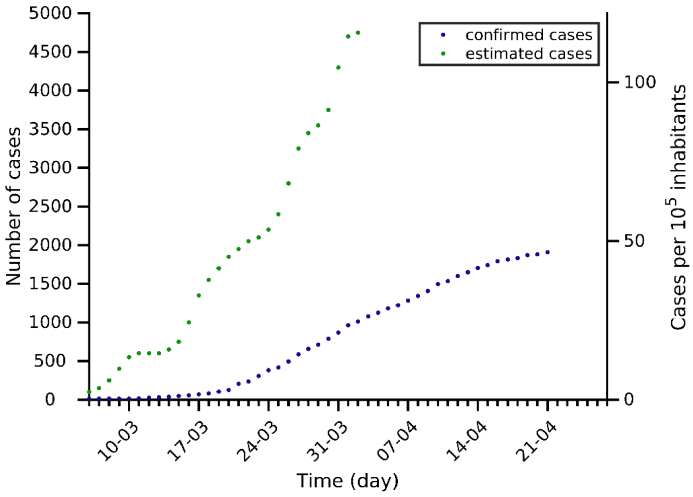


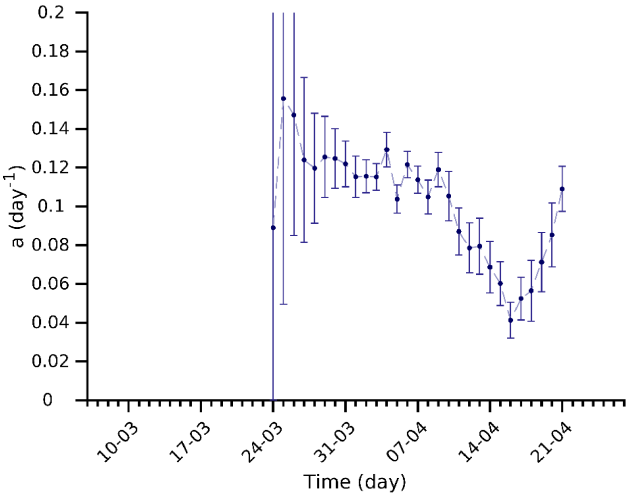


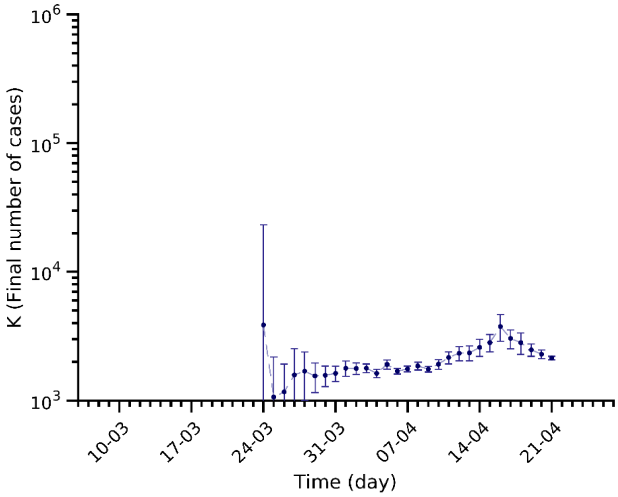


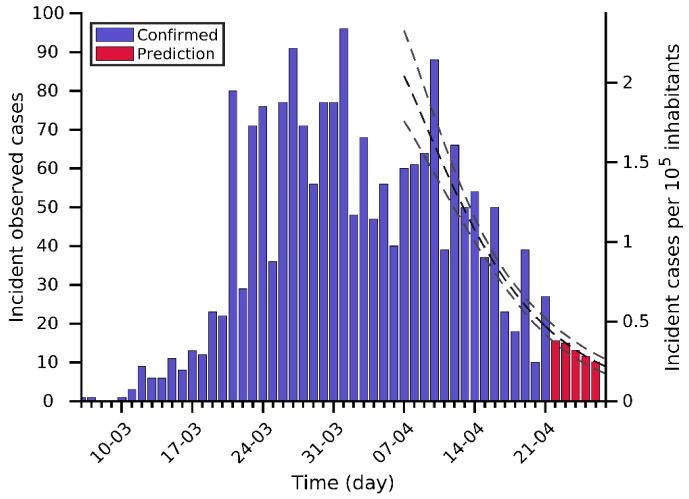
Croatia 21-04-2020. Population: 4.1M. Current cumulated incidence: $46/10^5$

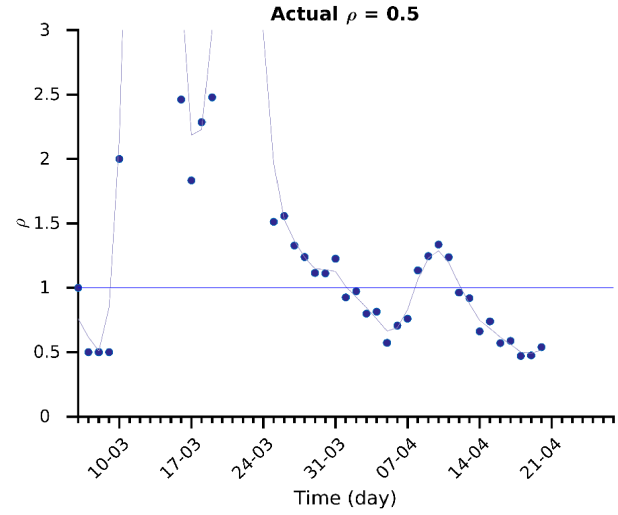


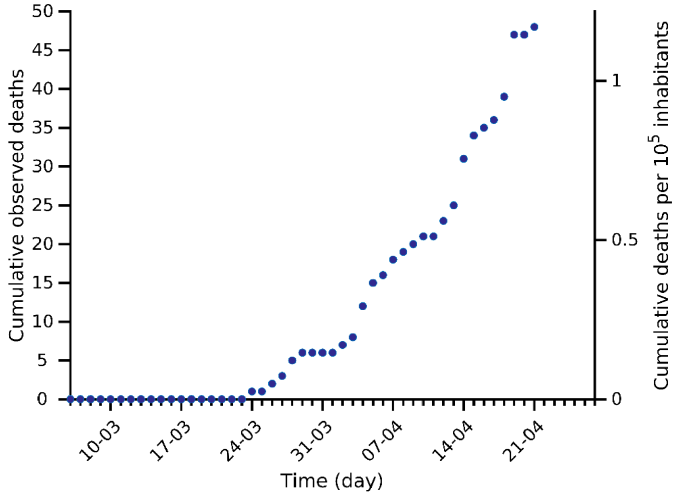


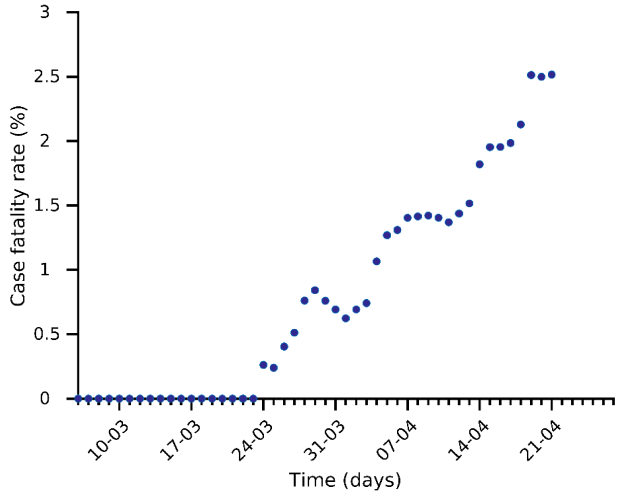




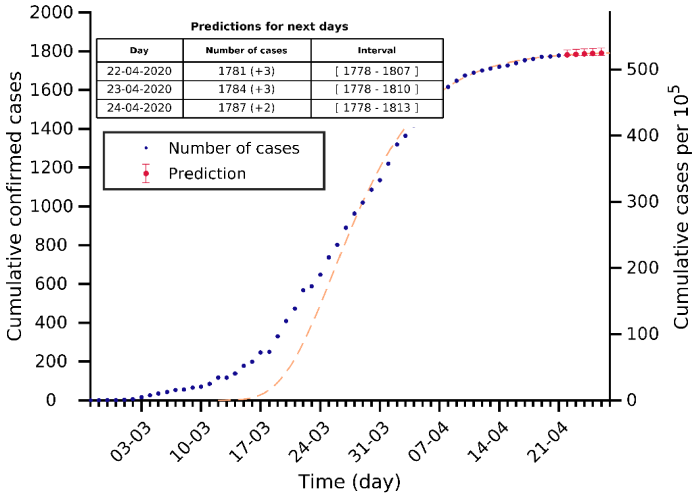


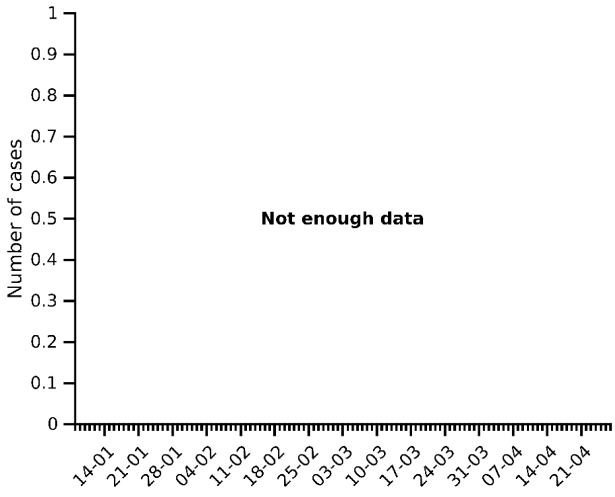


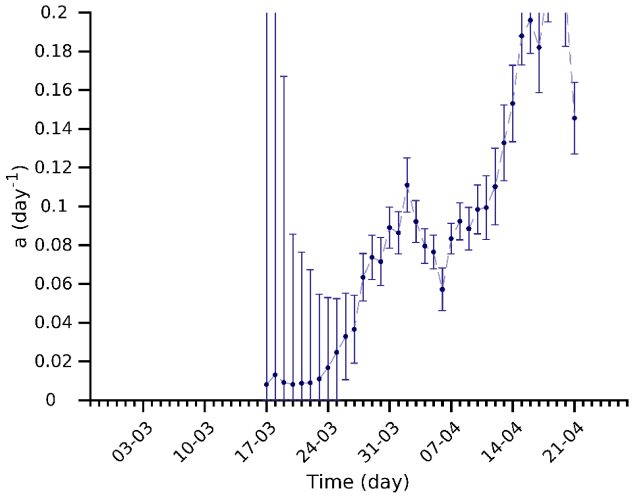


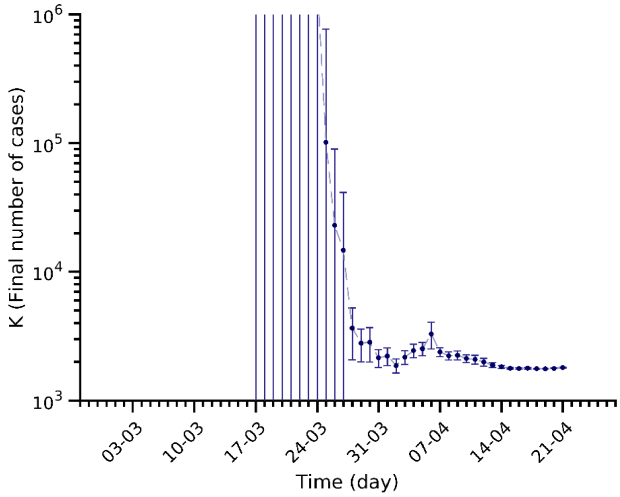


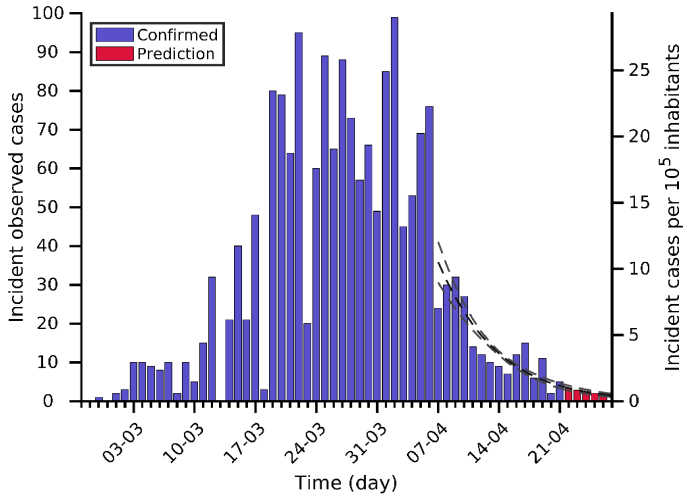
Iceland 21-04-2020. Population: 0.3M. Current cumulated incidence: $521/10^5$

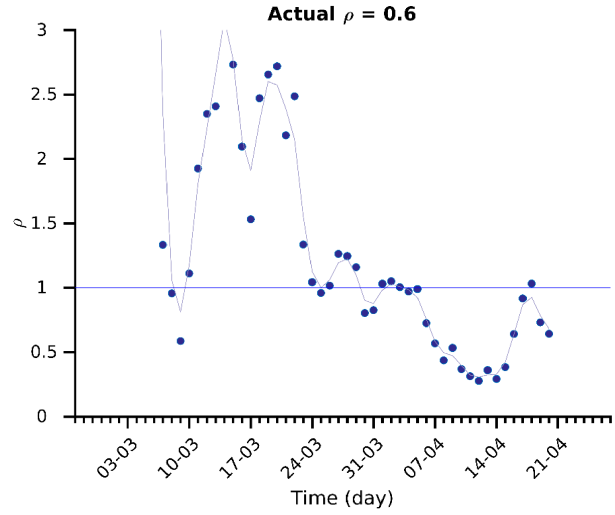


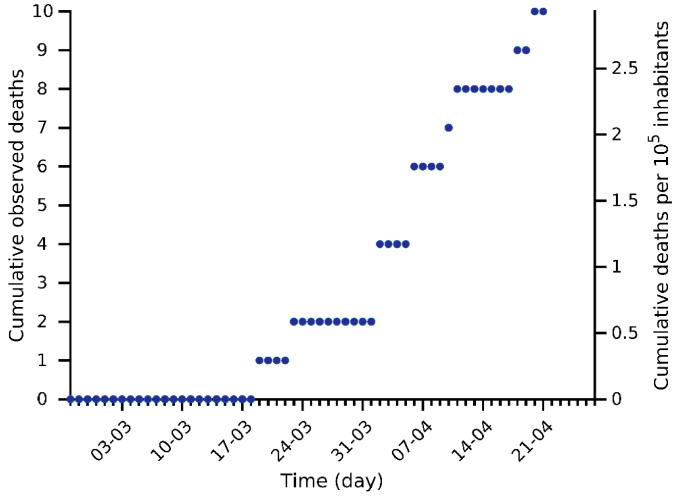


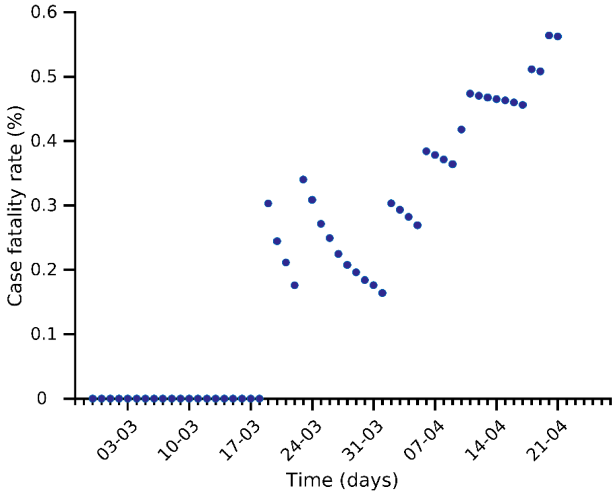




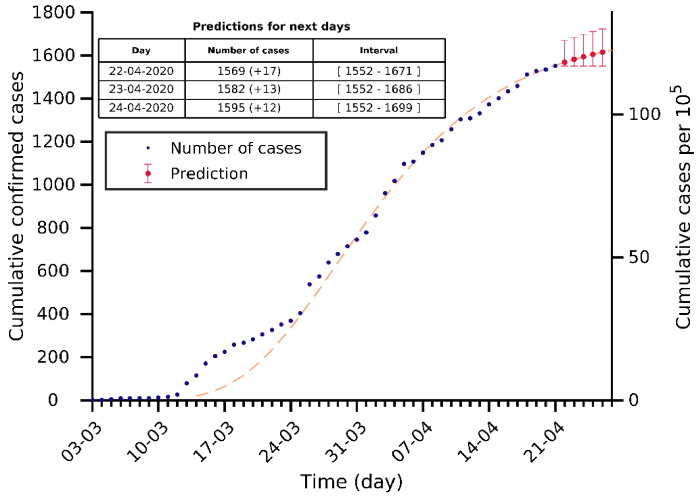


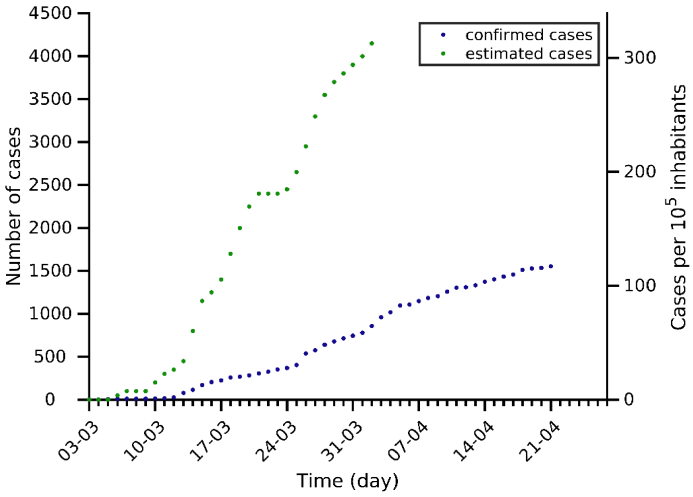


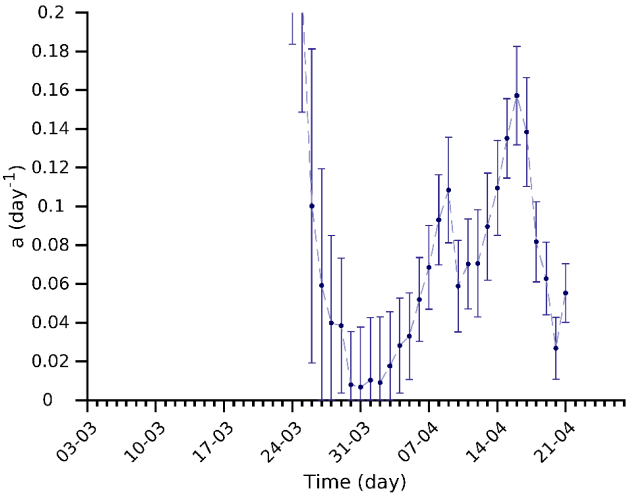


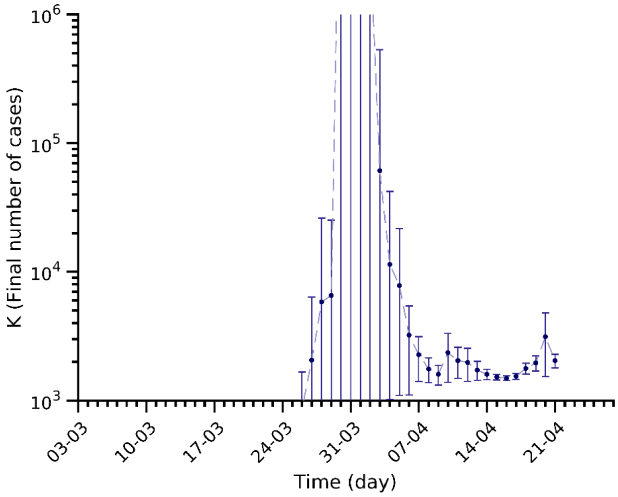


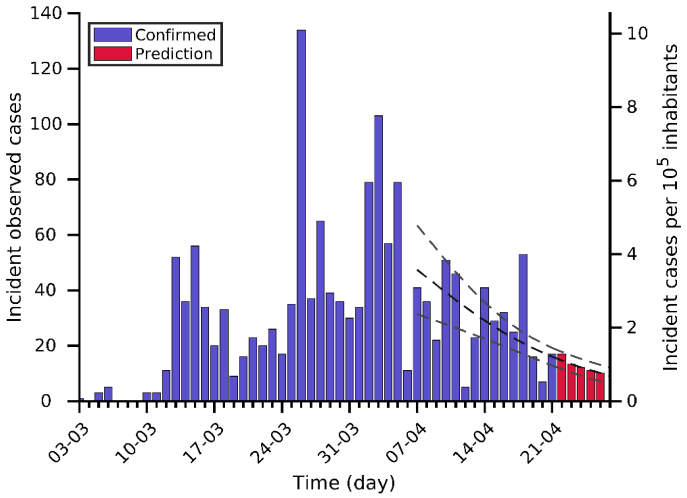
Estonia 21-04-2020. Population: 1.3M. Current cumulated incidence: 117/10⁵

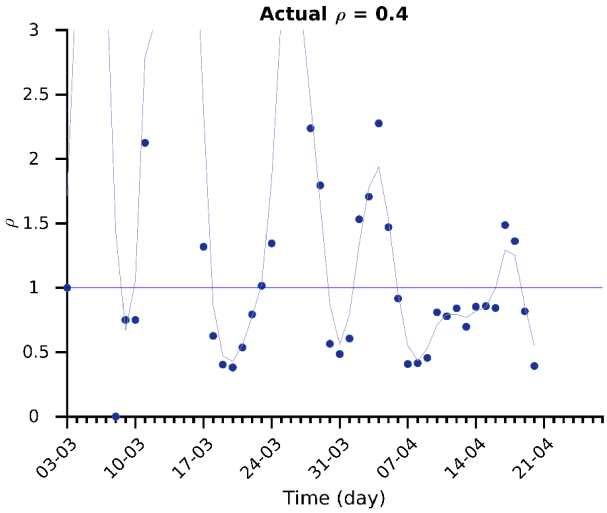


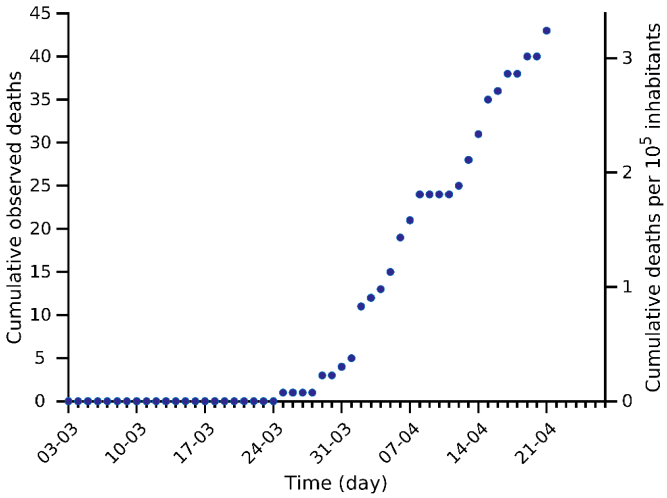


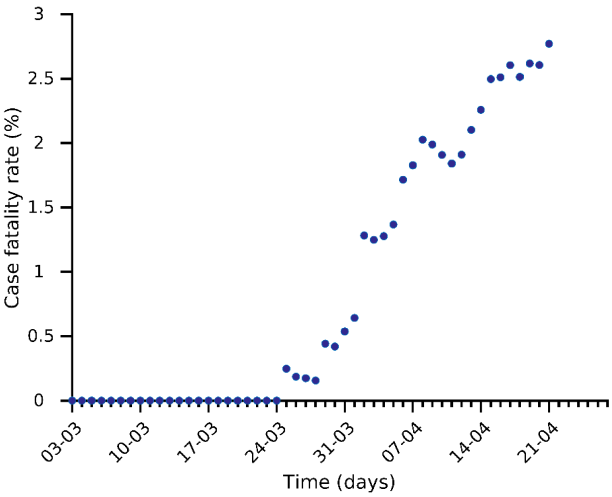




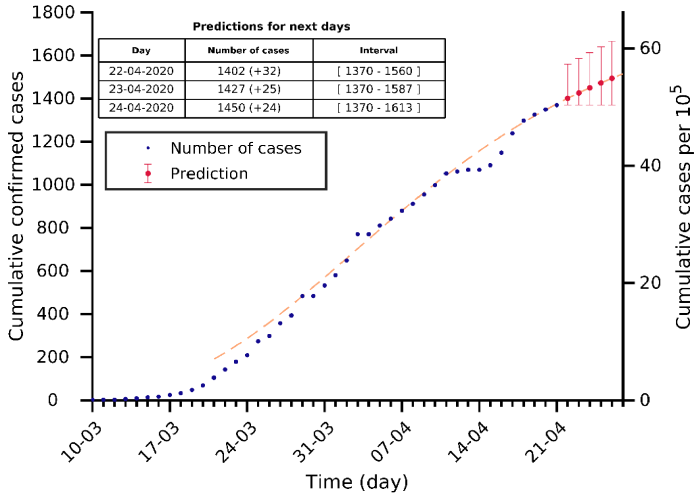


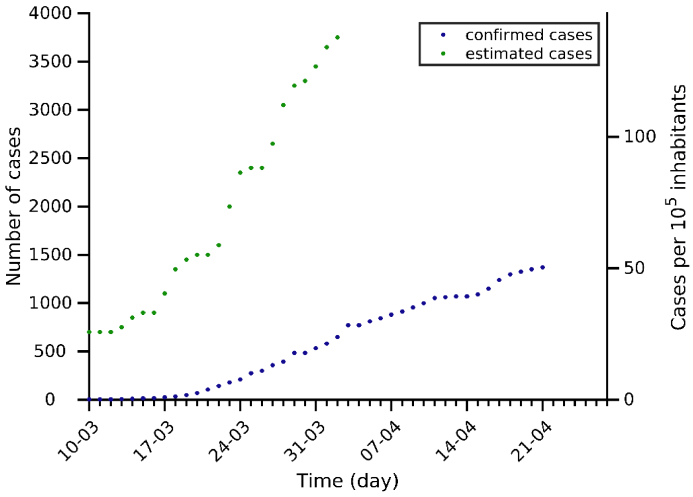


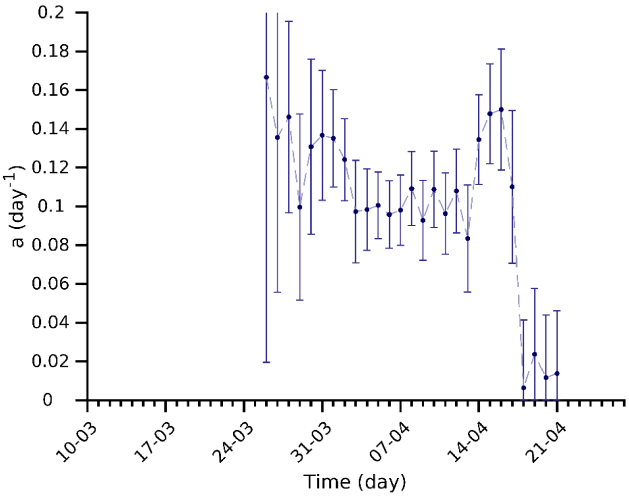


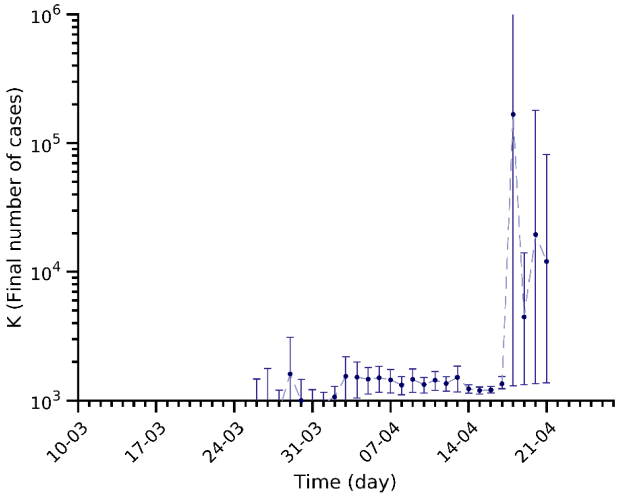


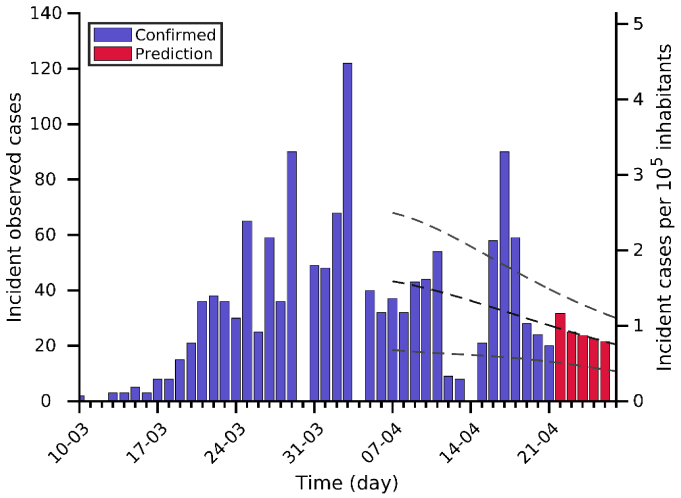
Lithuania 21-04-2020. Population: 2.7M. Current cumulated incidence: $50/10^5$

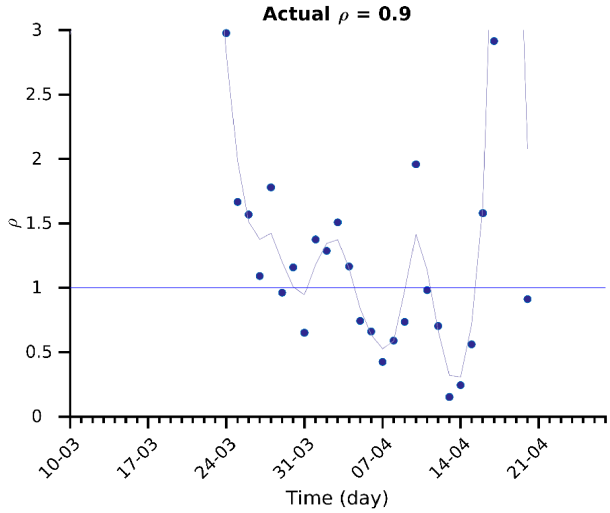


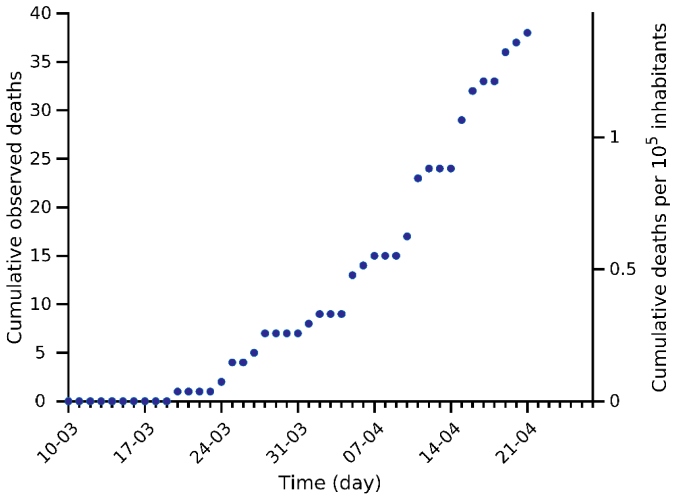


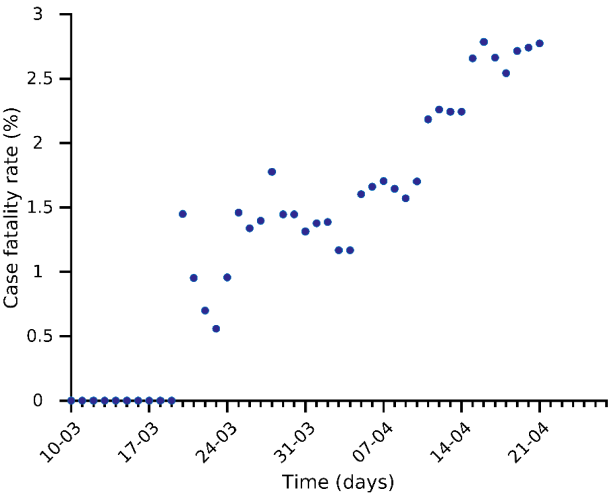




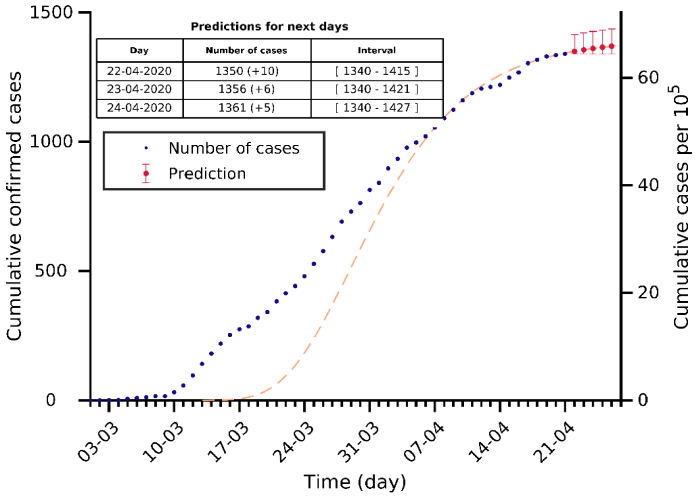


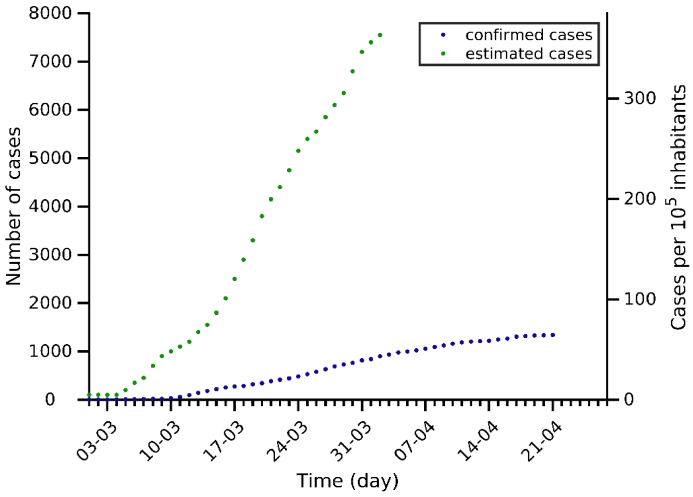


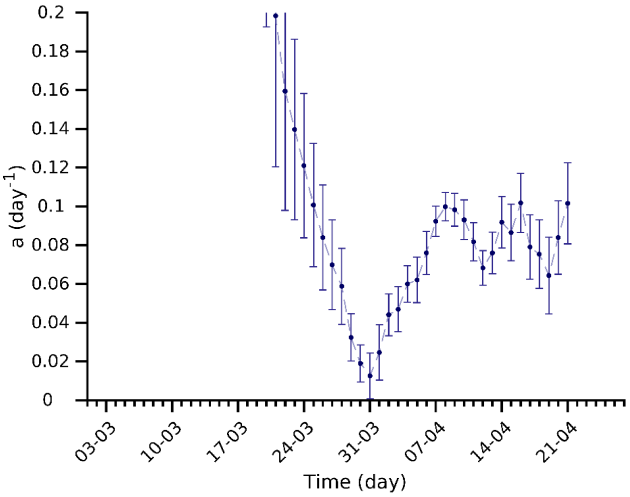


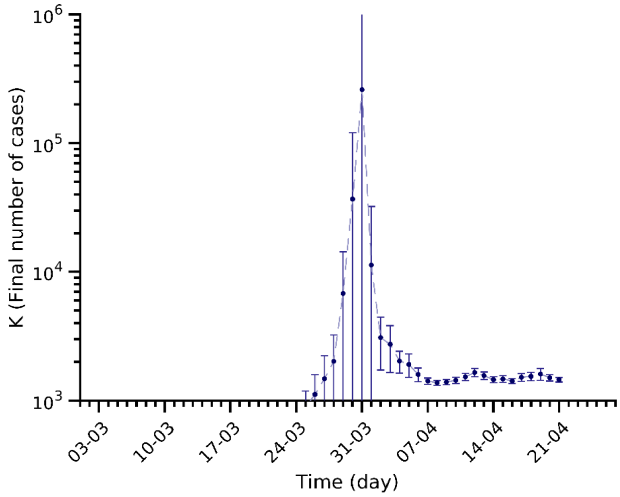


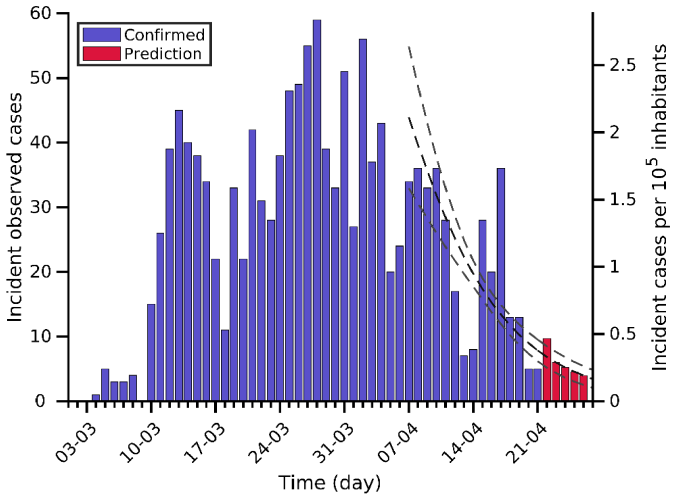
Slovenia 21-04-2020. Population: 2.1M. Current cumulated incidence: 64/10^5

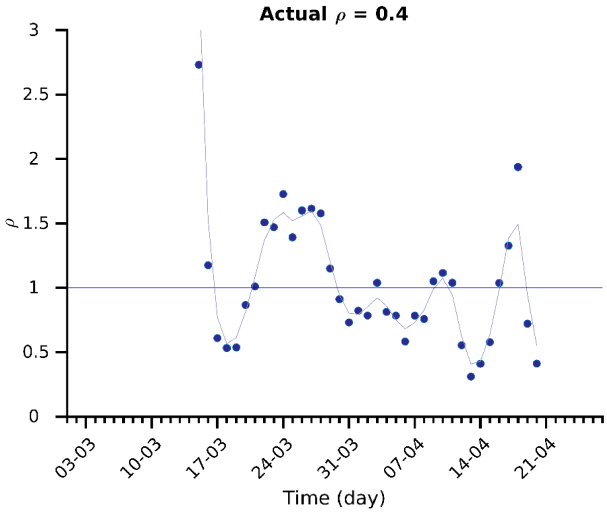


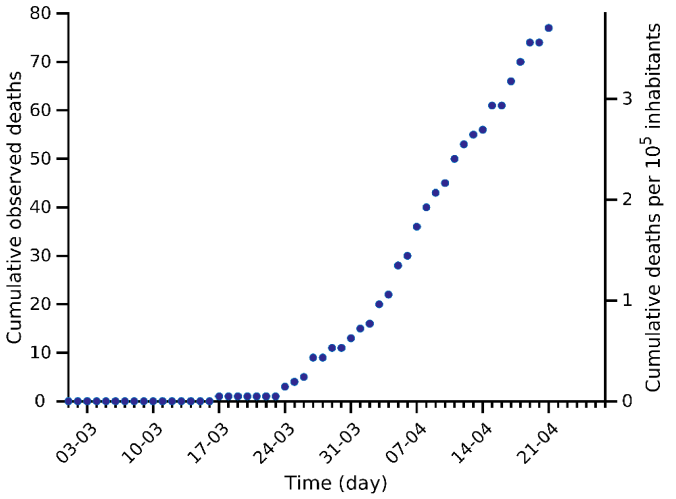


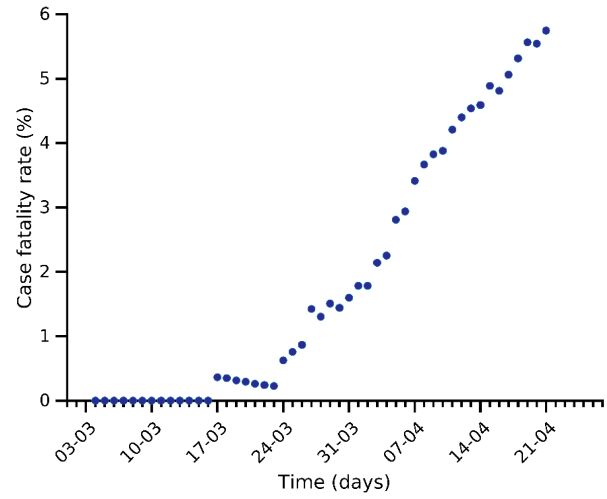




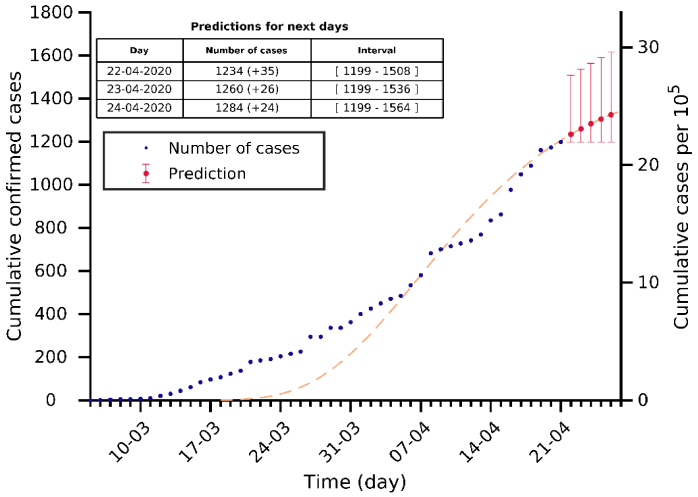


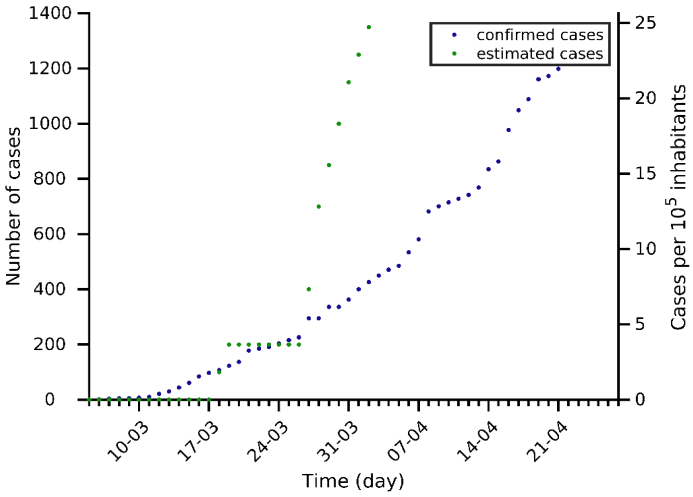


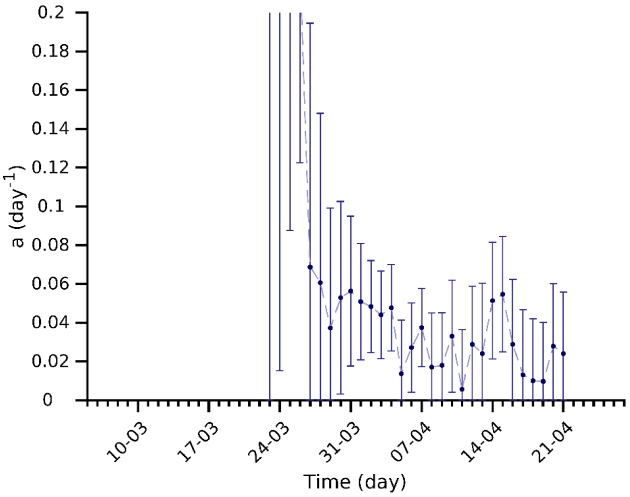


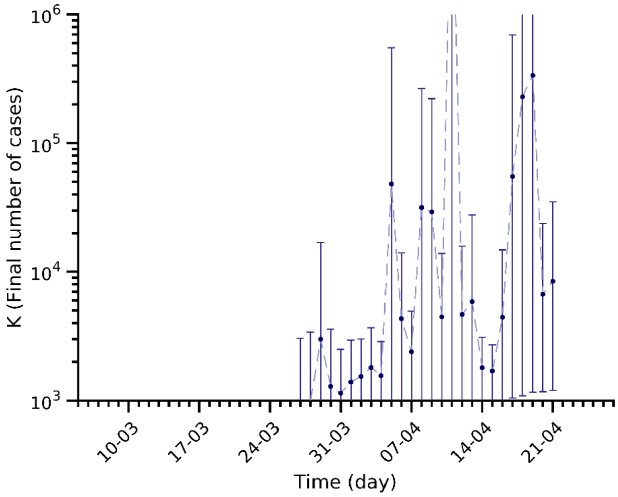


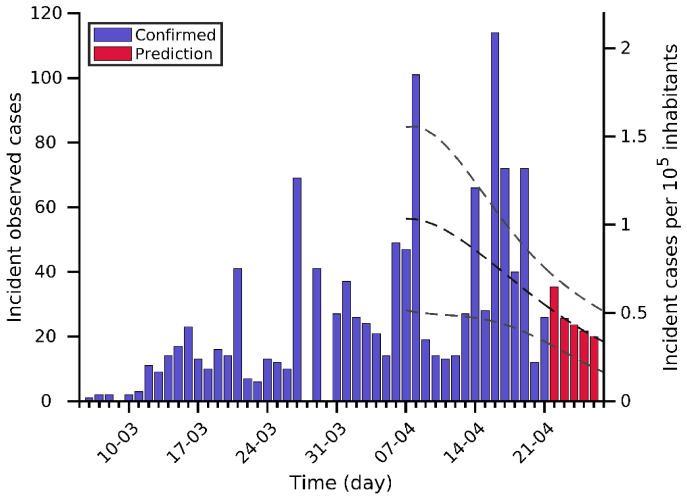
Slovakia 21-04-2020. Population: 5.5M. Current cumulated incidence: 22/10^5

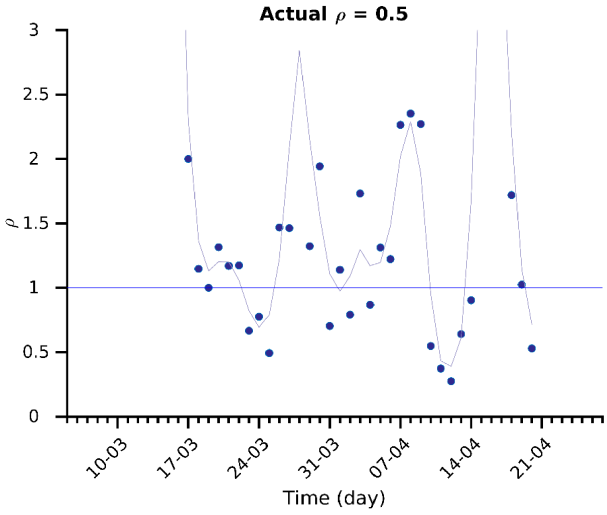


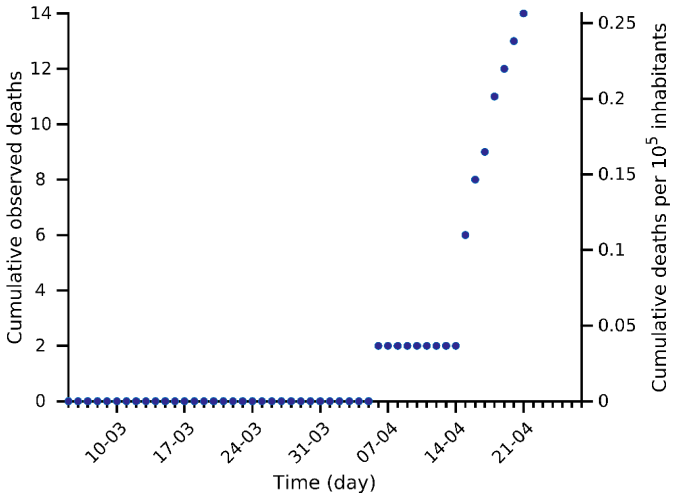


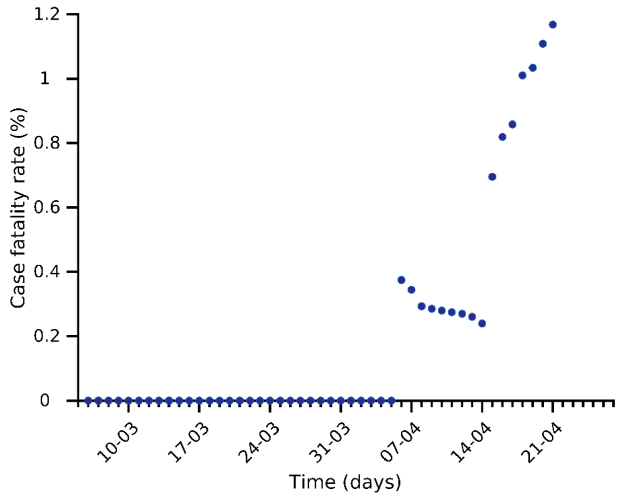




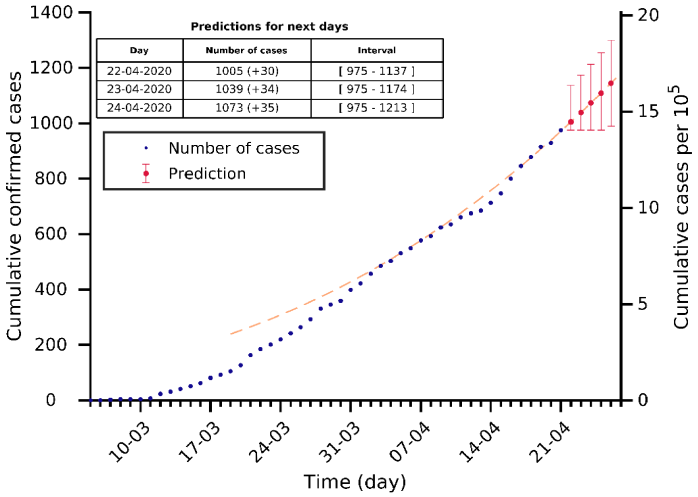


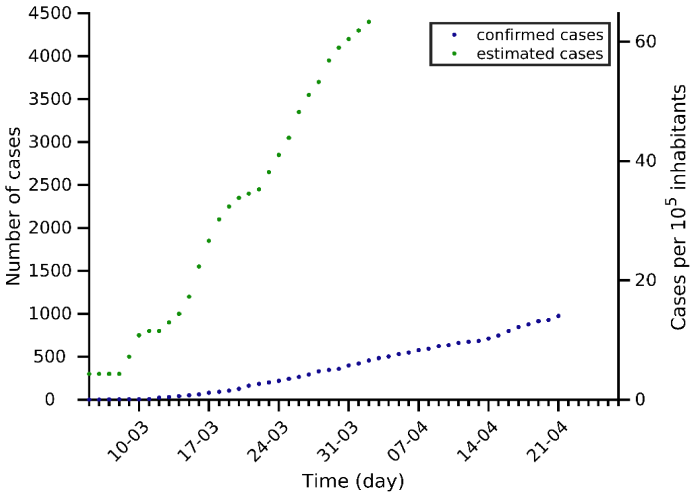


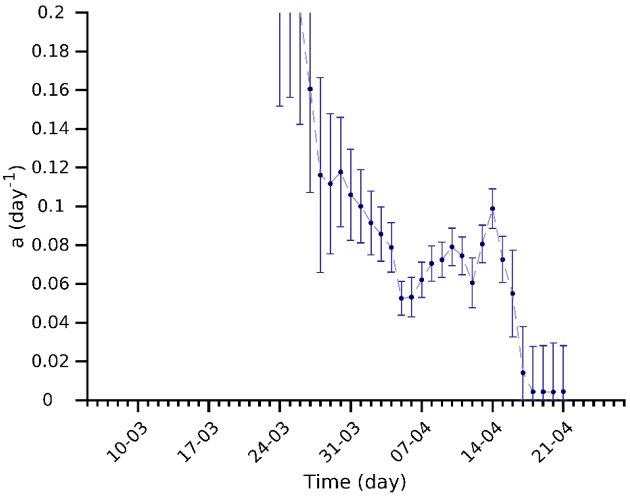


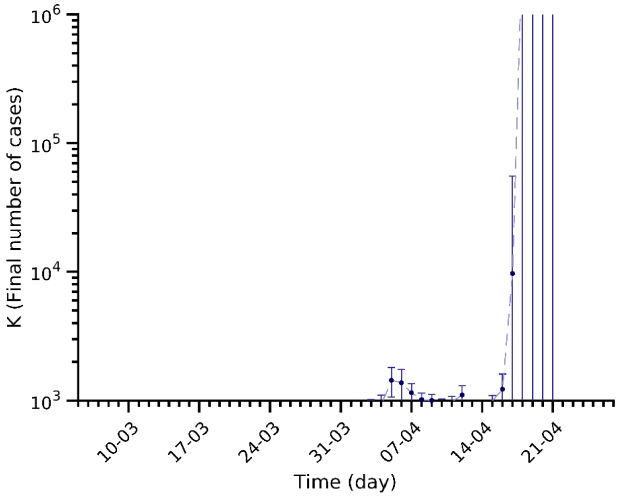


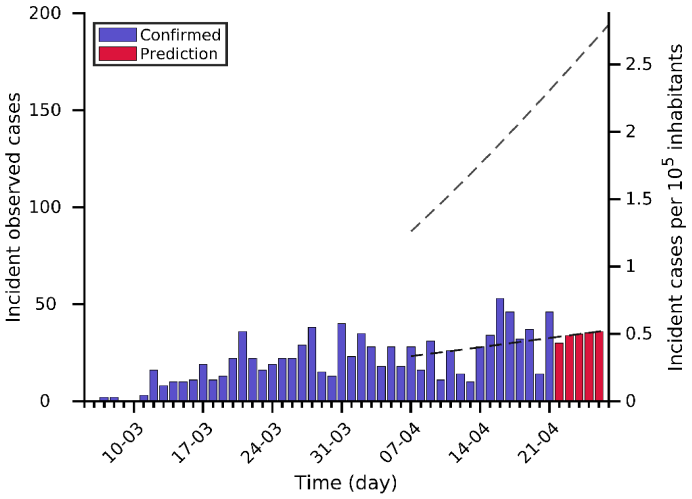
Bulgaria 21-04-2020. Population: 6.9M. Current cumulated incidence: 14/10^5

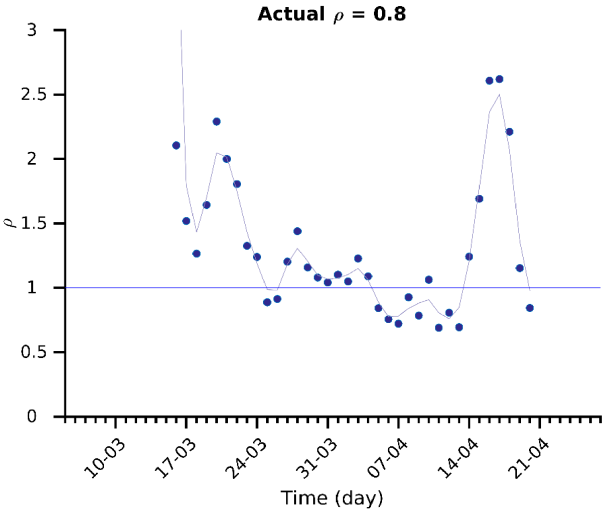


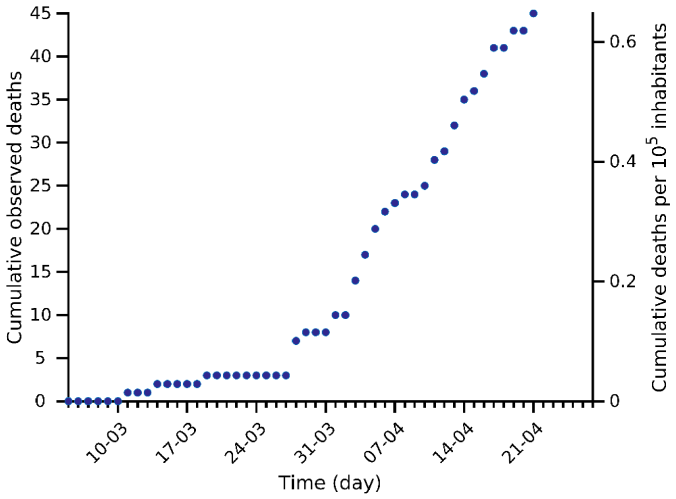


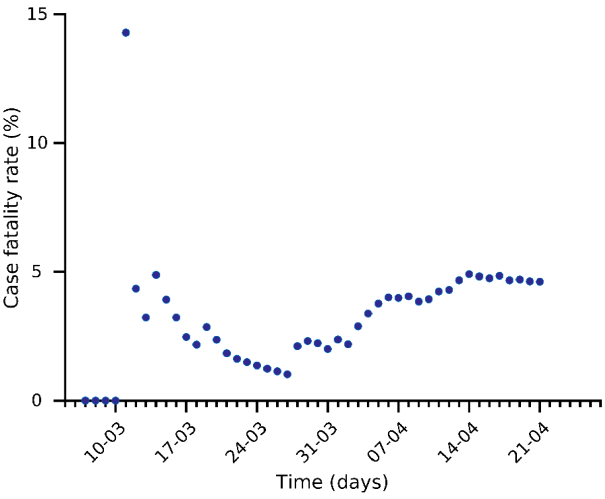




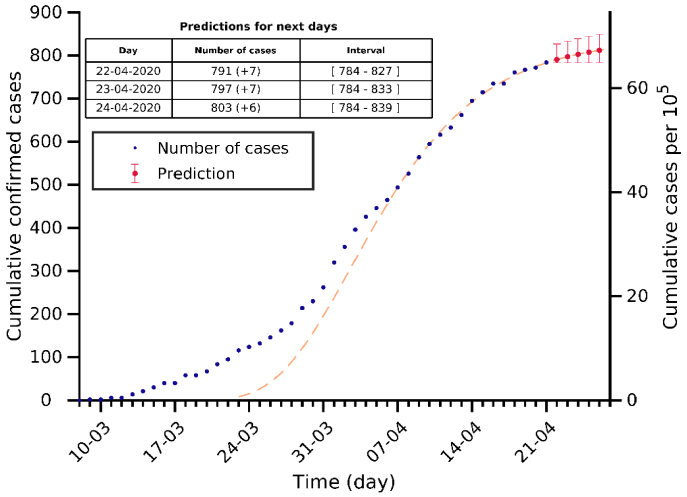


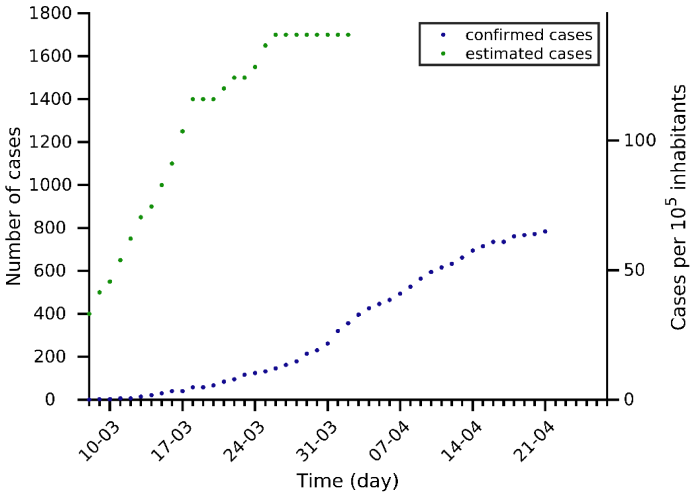


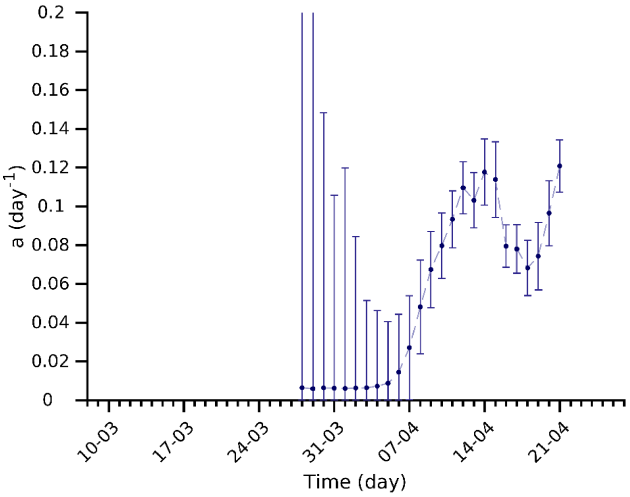


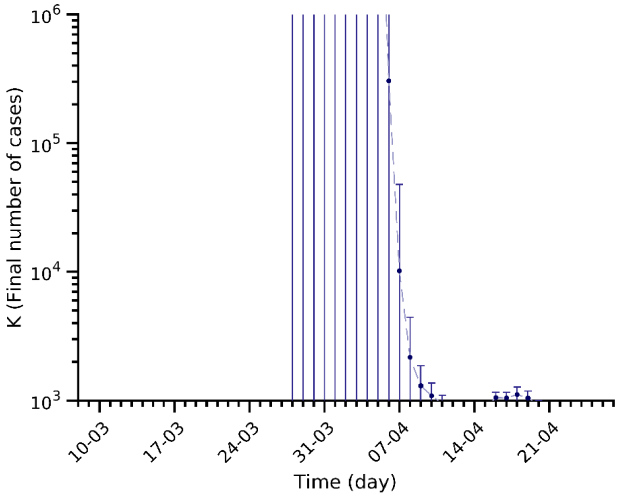


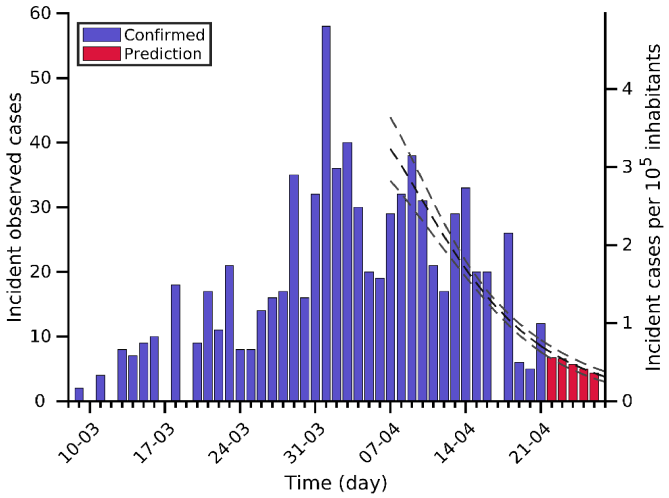
Cyprus 21-04-2020. Population: 1.2M. Current cumulated incidence: 65/10^5

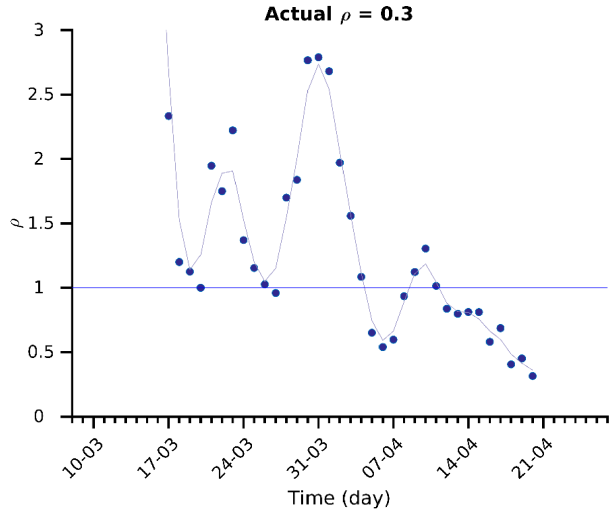


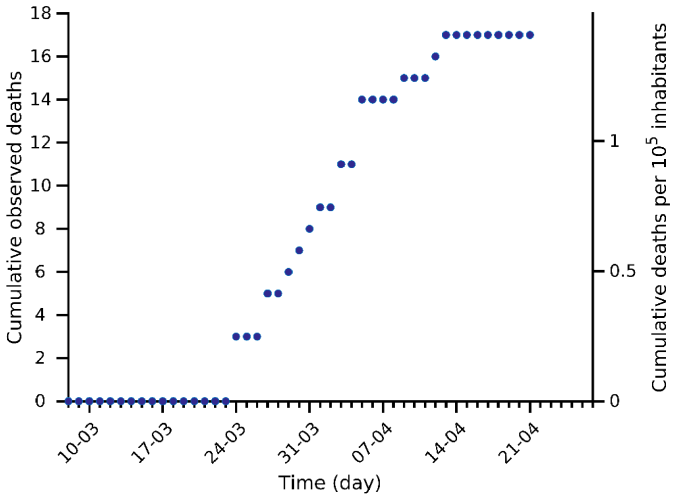


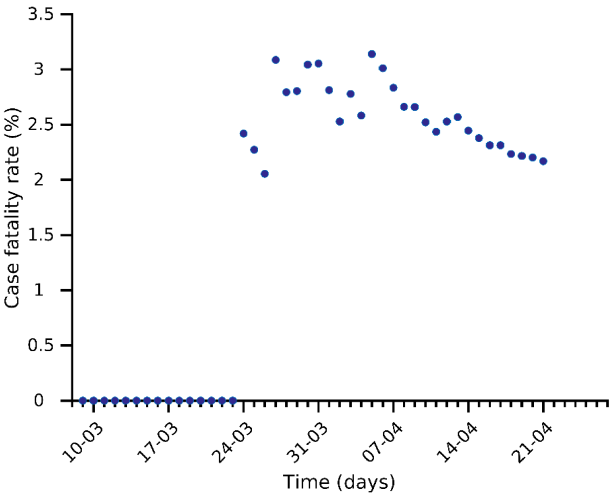




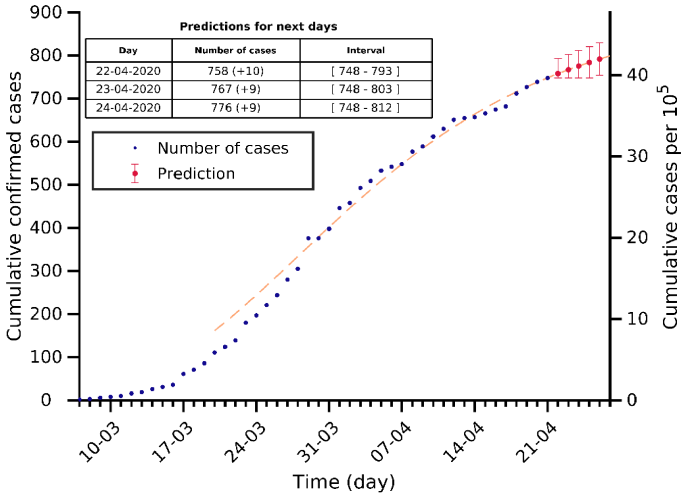


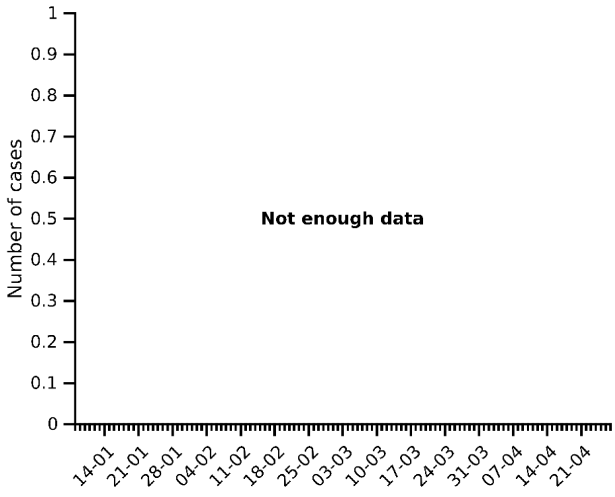


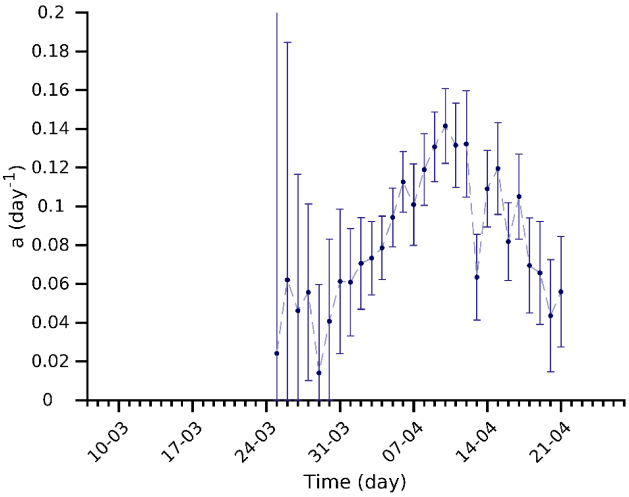


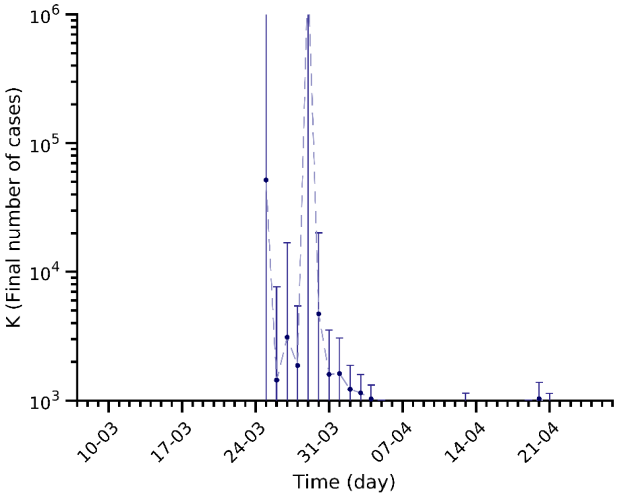


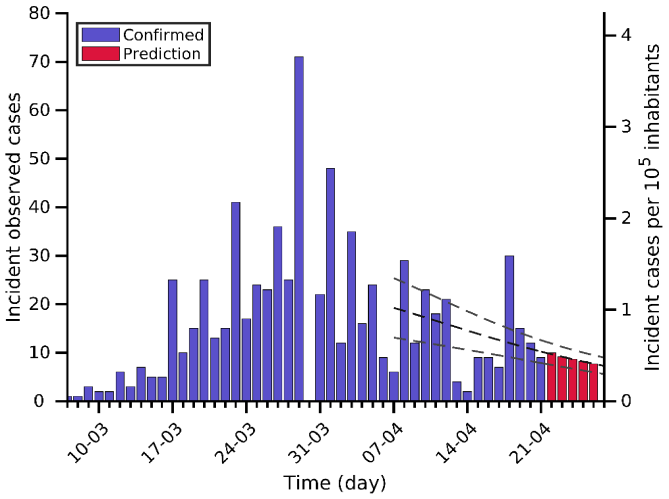
Latvia 21-04-2020. Population: 1.9M. Current cumulated incidence: 40/10^5

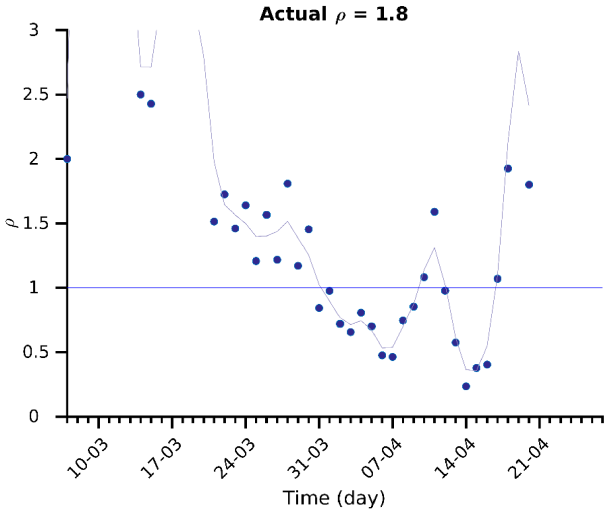


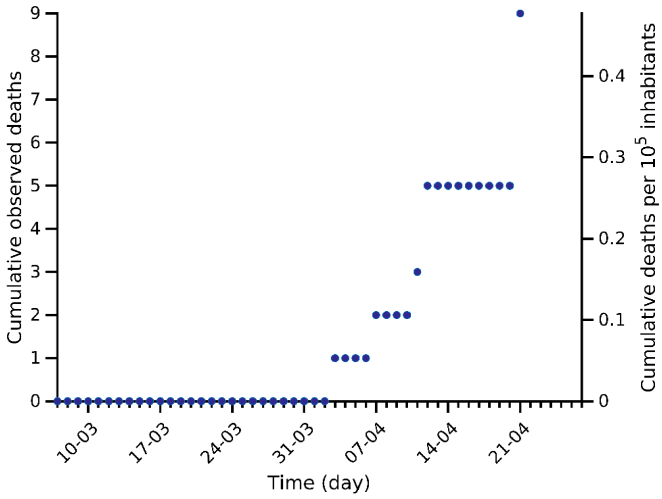


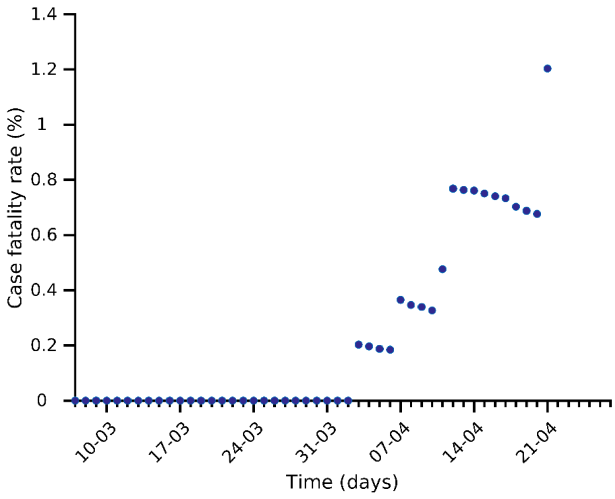




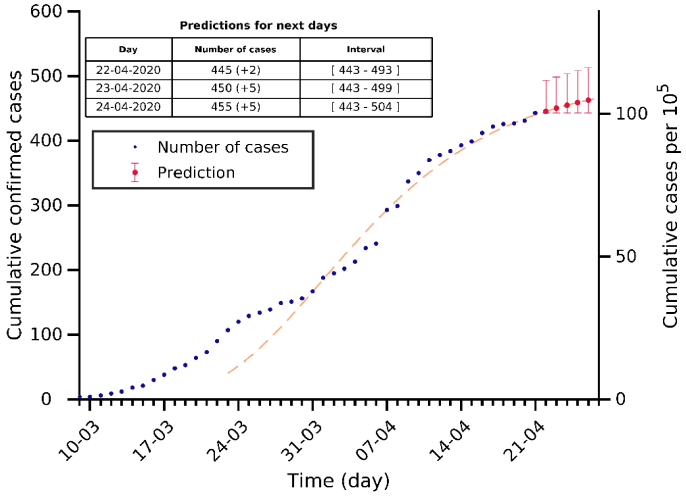


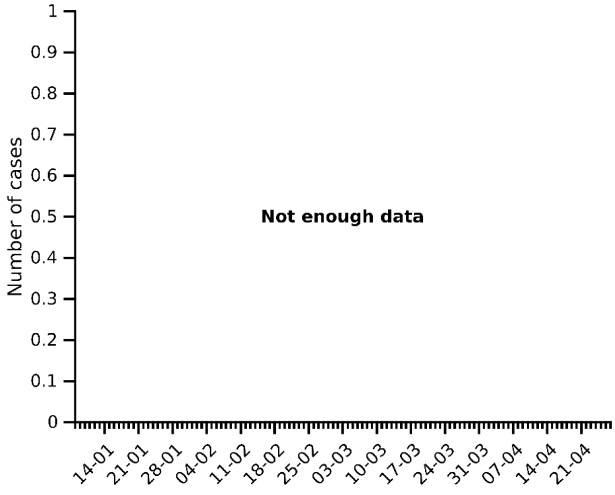


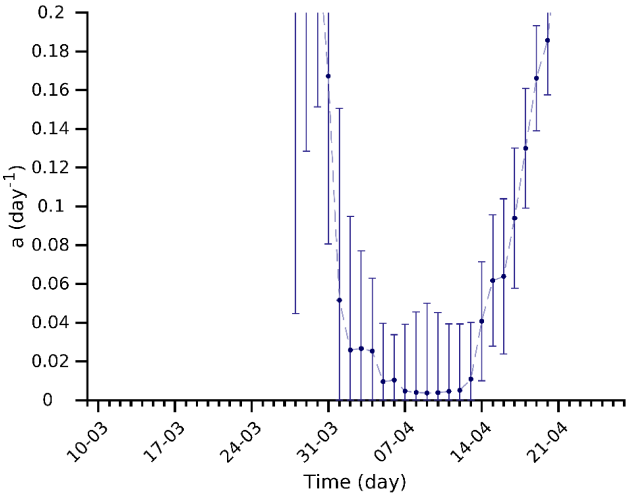


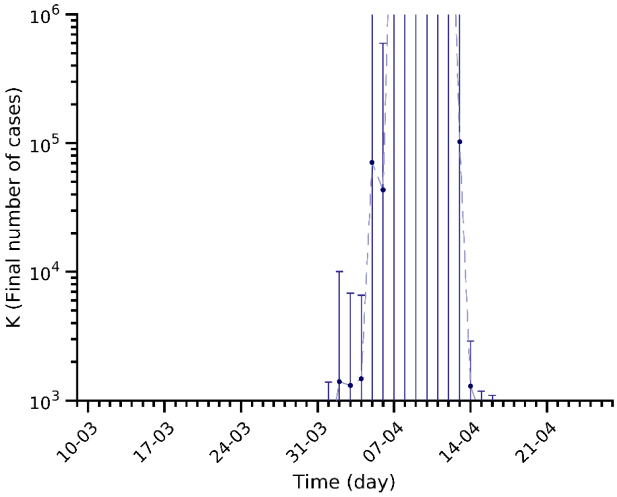


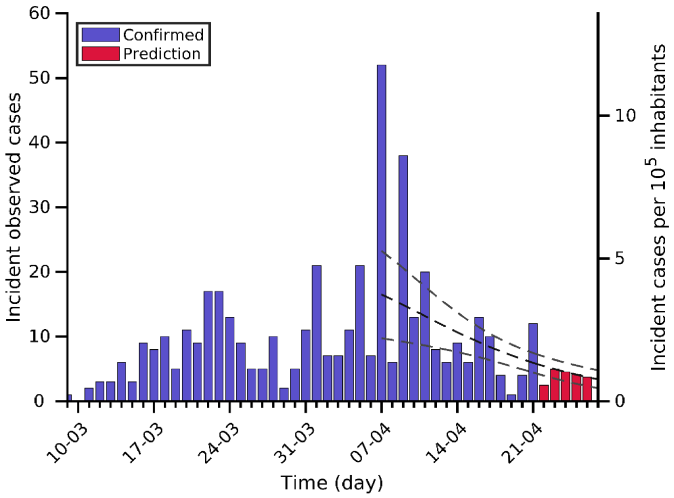
Malta 21-04-2020. Population: 0.4M. Current cumulated incidence: $100/10^5$

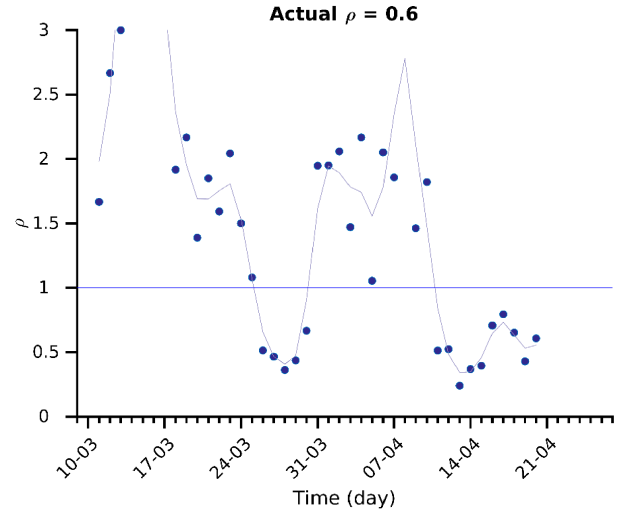


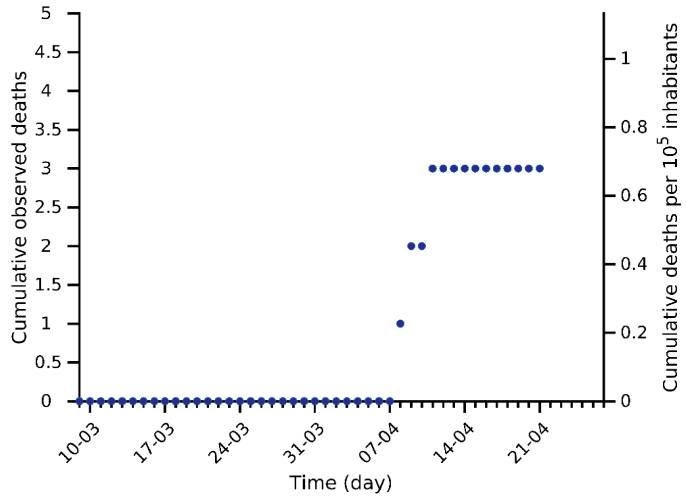


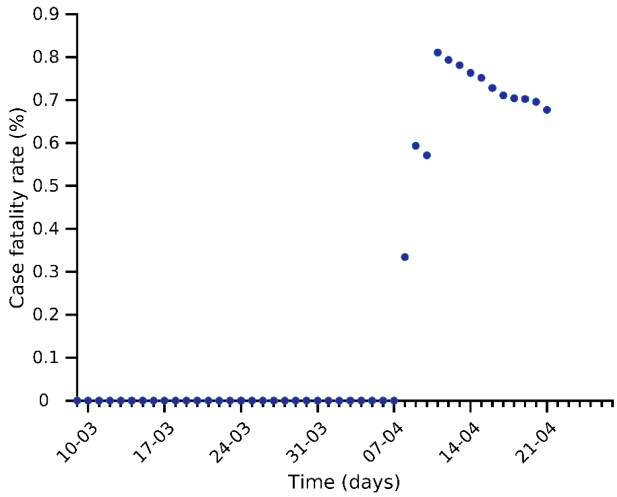








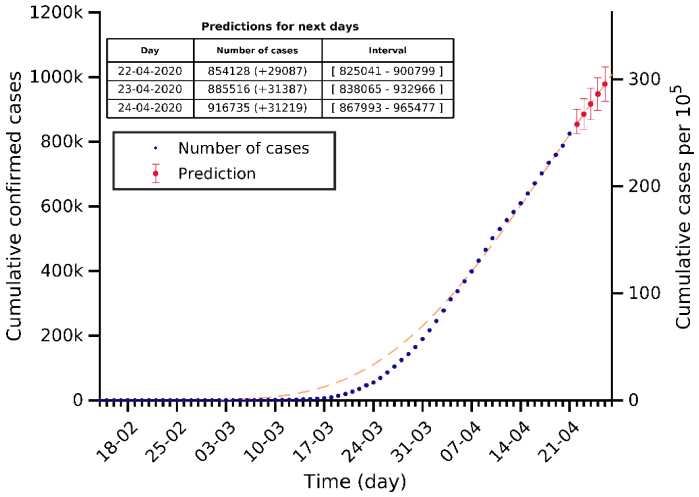


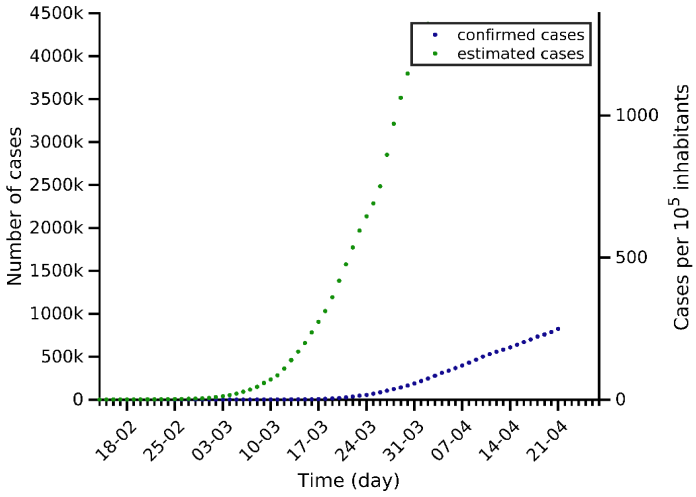


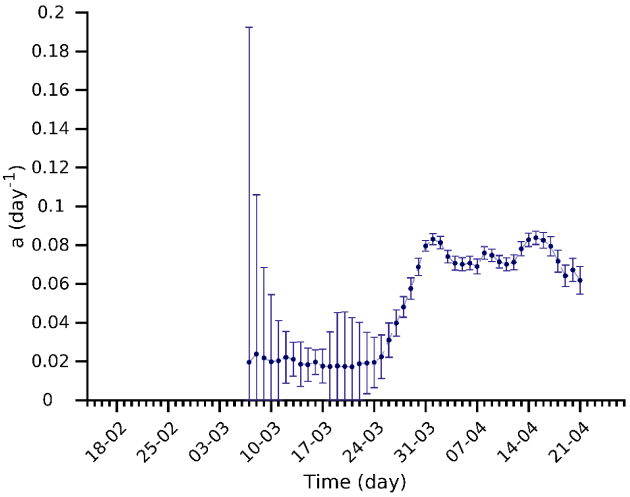
(2) Analysis and prediction of COVID-19 for other countries

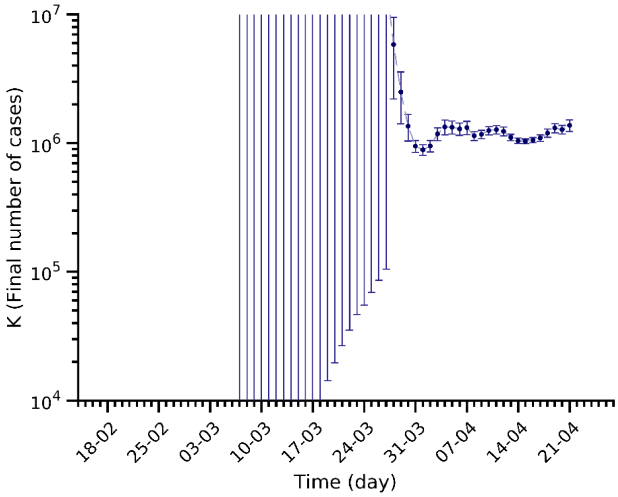
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

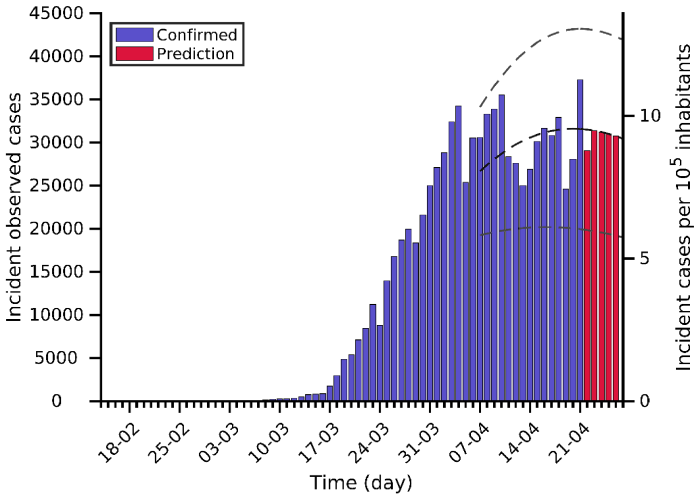
USA 21-04-2020. Population: 331.0M. Current cumulated incidence: 249/10^5

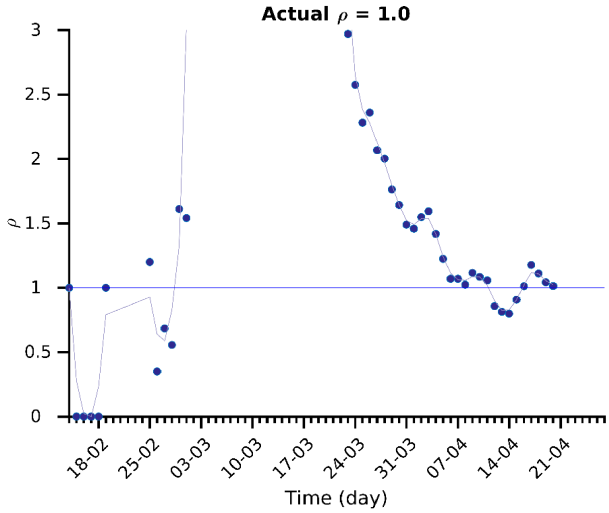


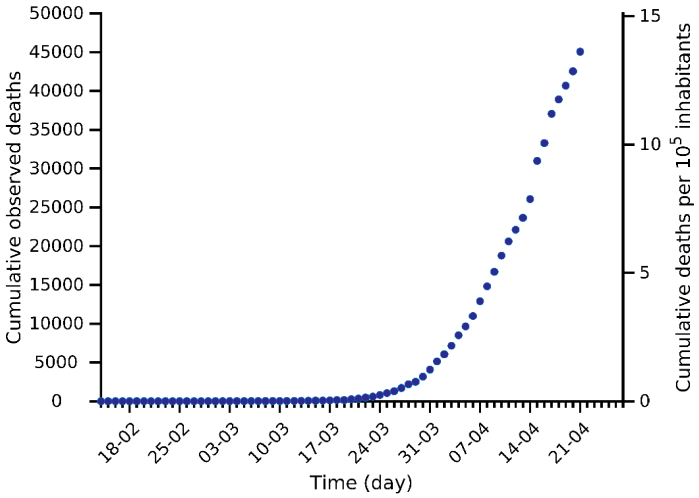


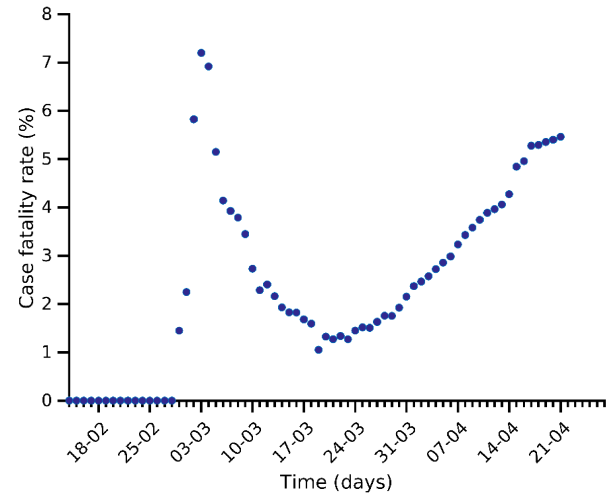




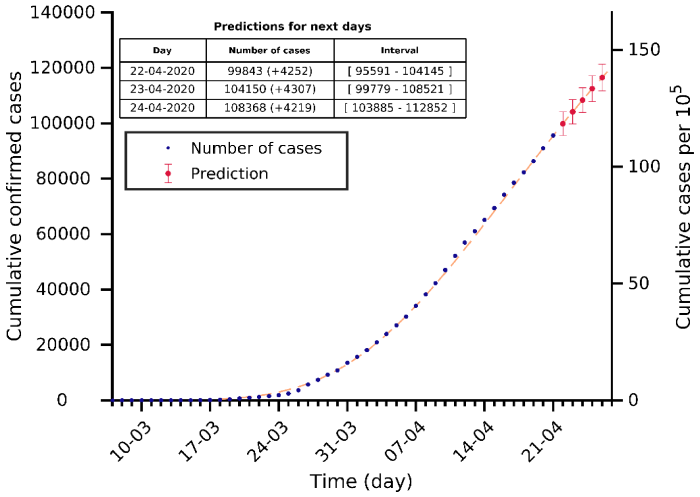


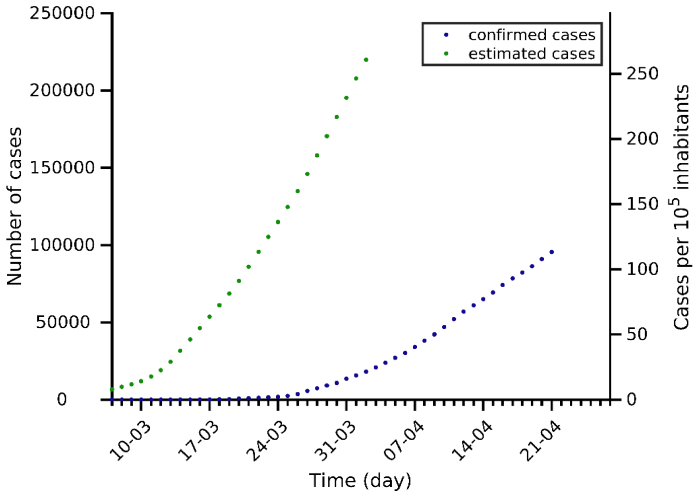


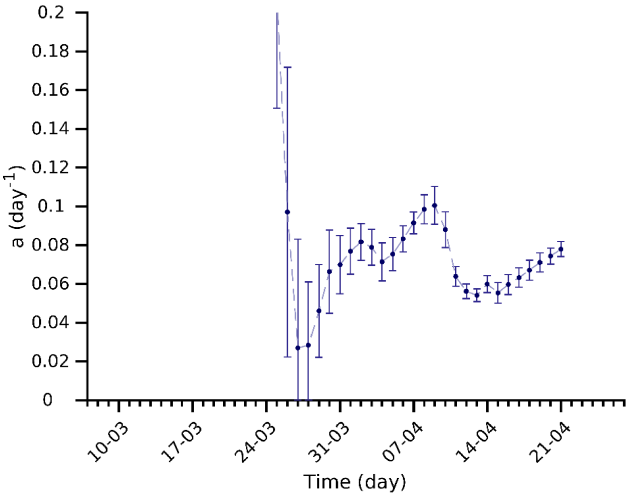


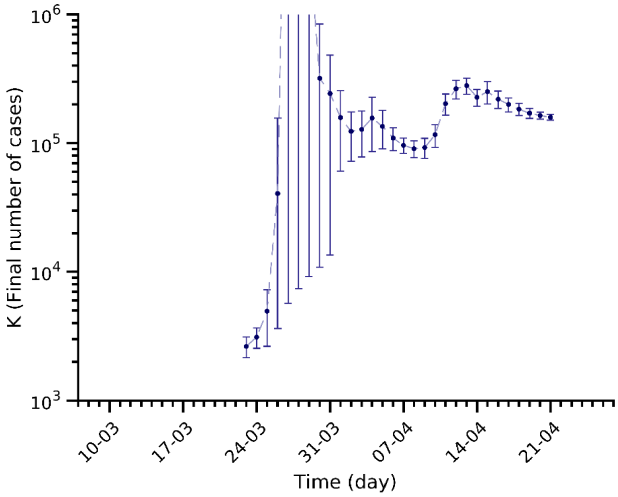


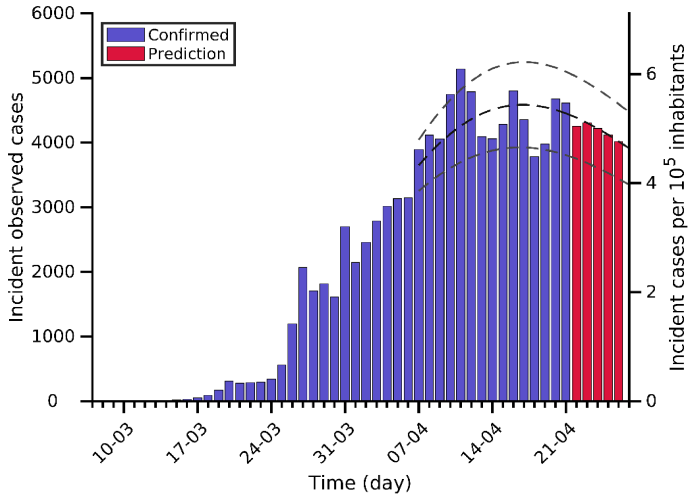
Turkey 21-04-2020. Population: 84.3M. Current cumulated incidence: 113/10^5

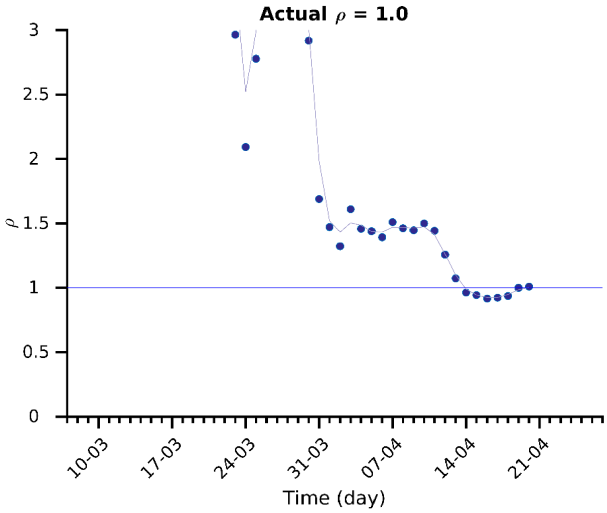


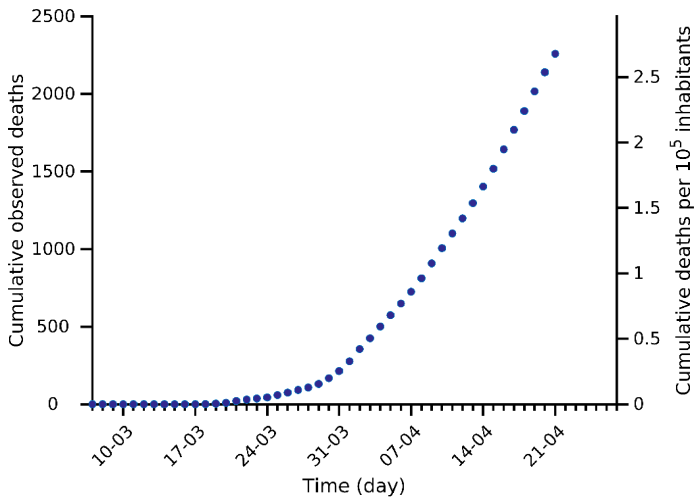


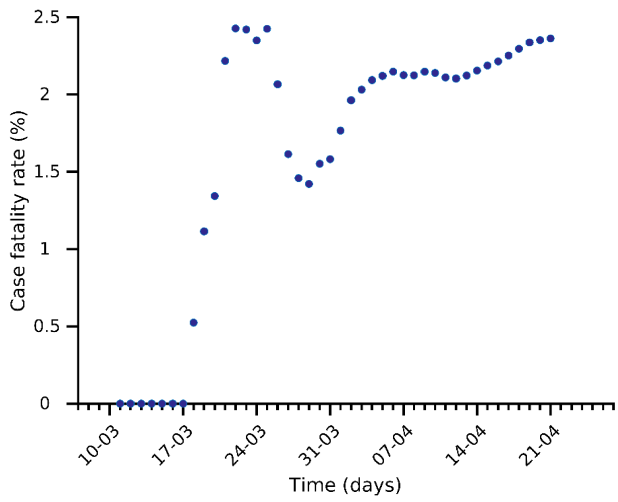




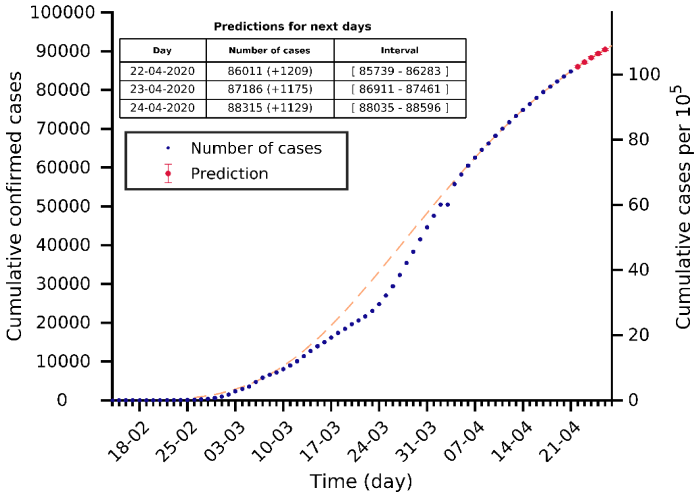


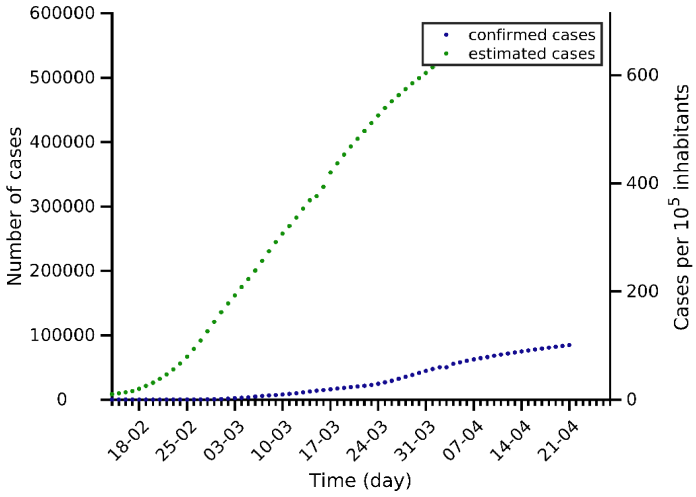


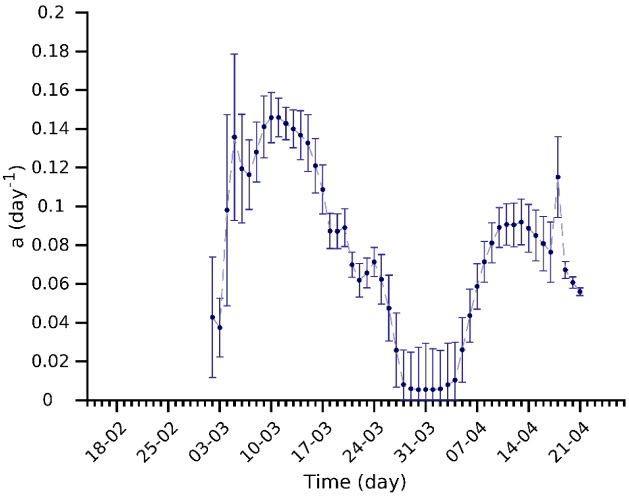


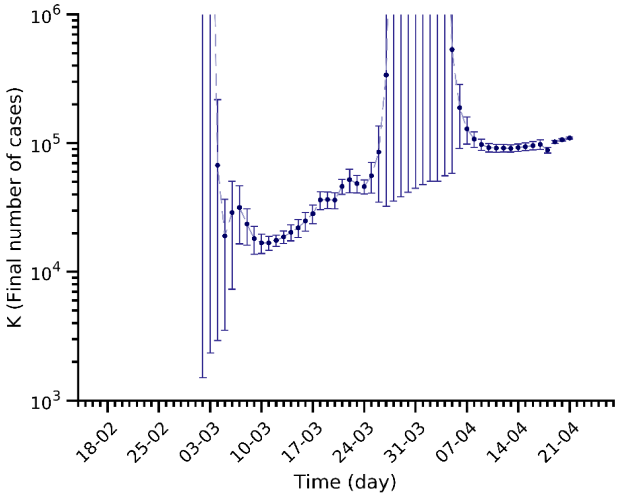


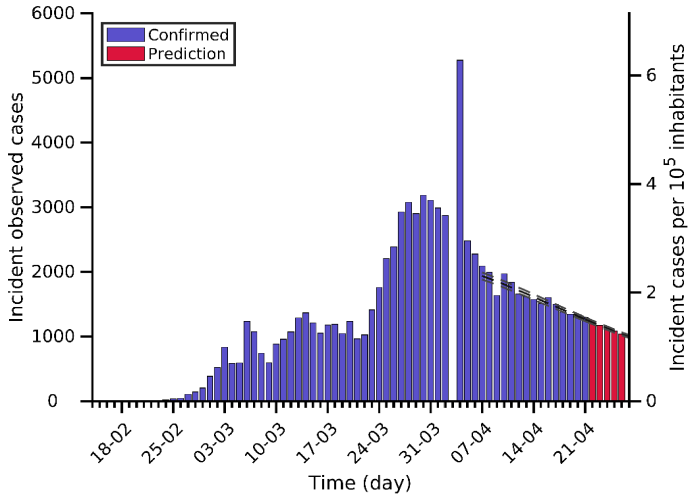
Iran 21-04-2020. Population: 84.0M. Current cumulated incidence: 101/10^5

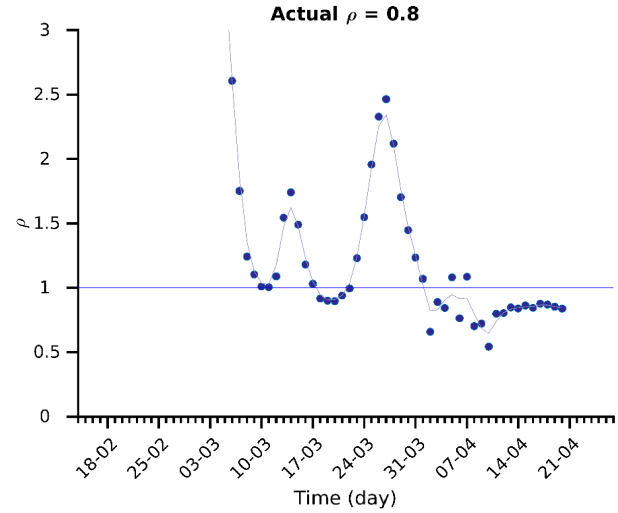


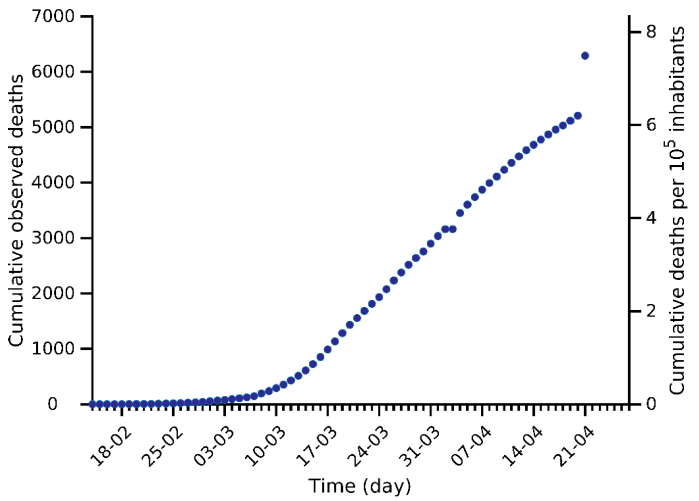


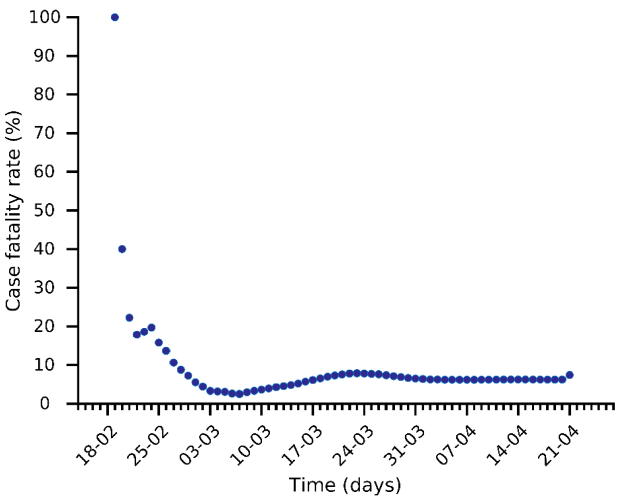




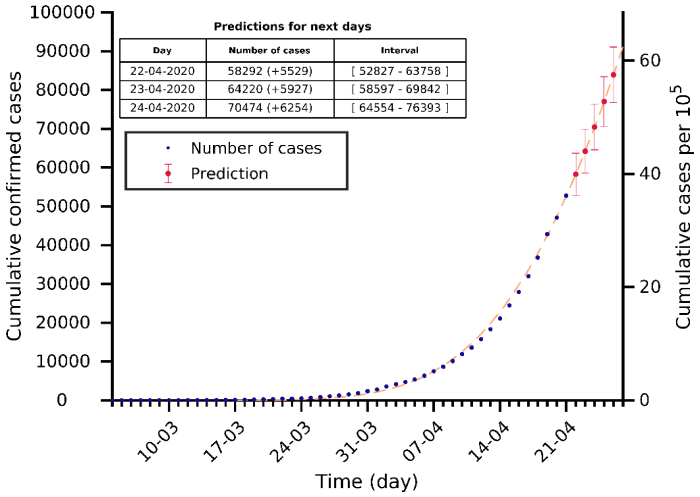


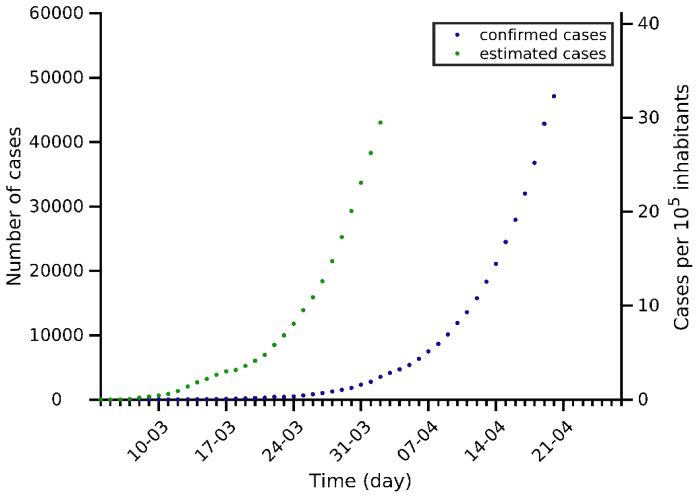


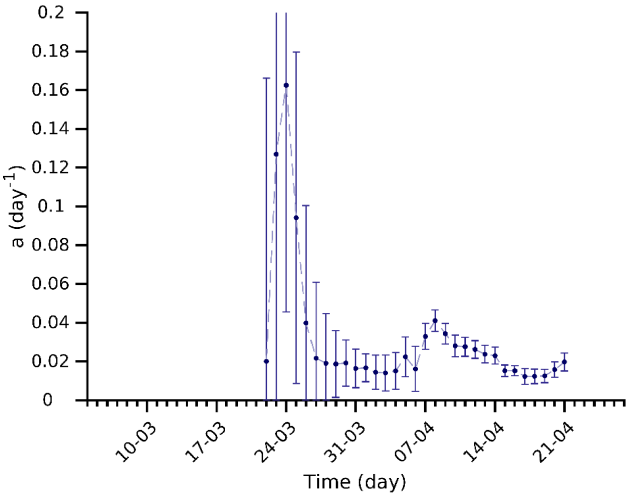


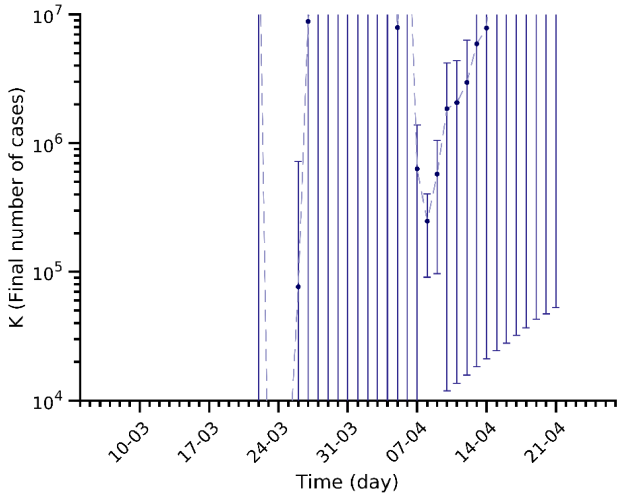


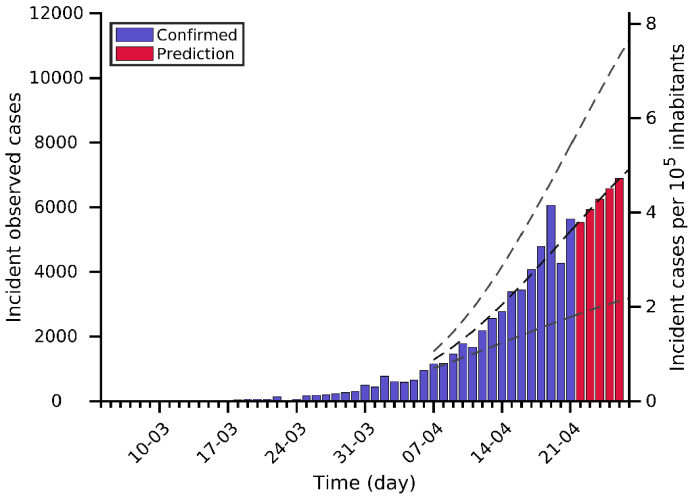
Russia 21-04-2020. Population: 145.9M. Current cumulated incidence: $36/10^5$

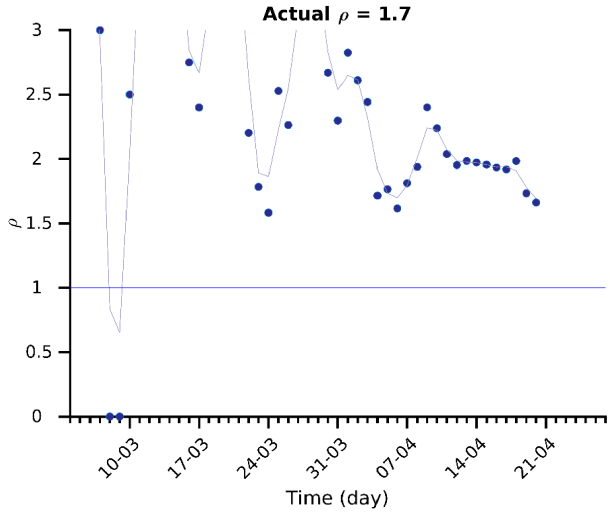


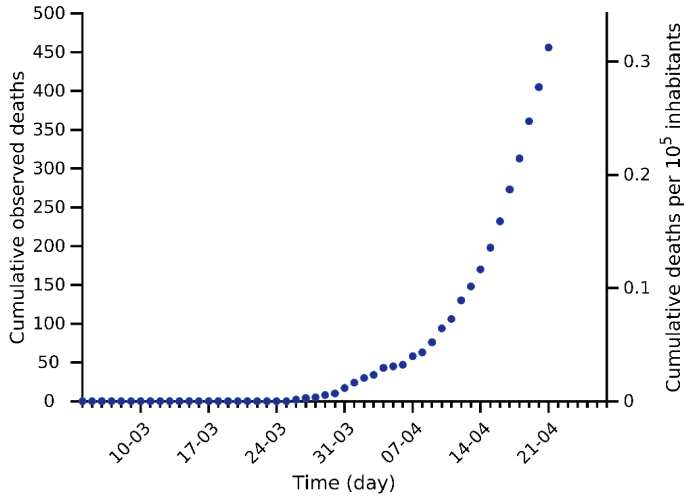


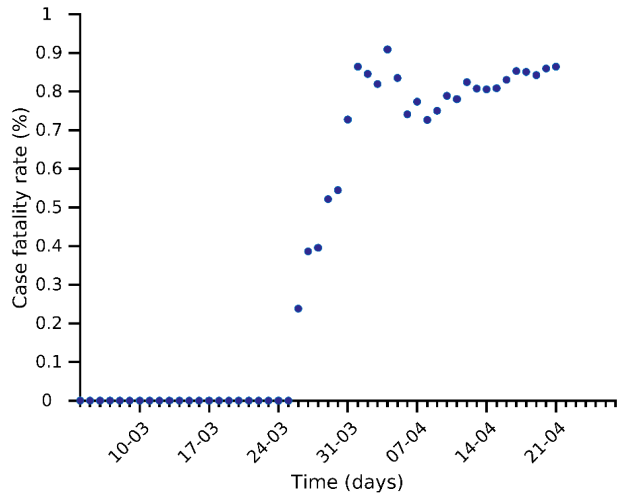




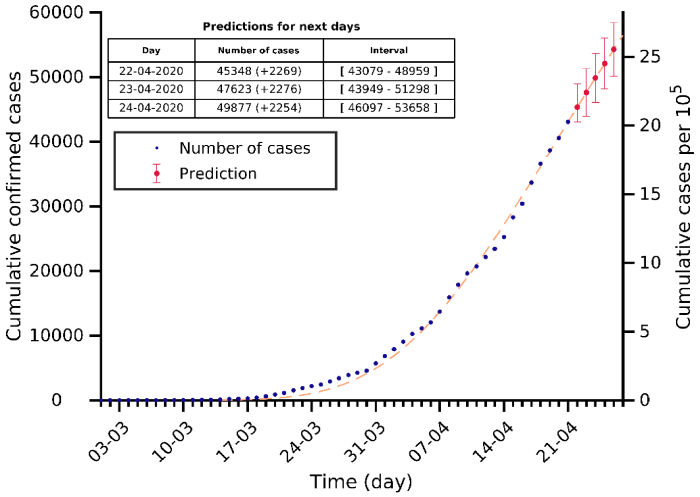


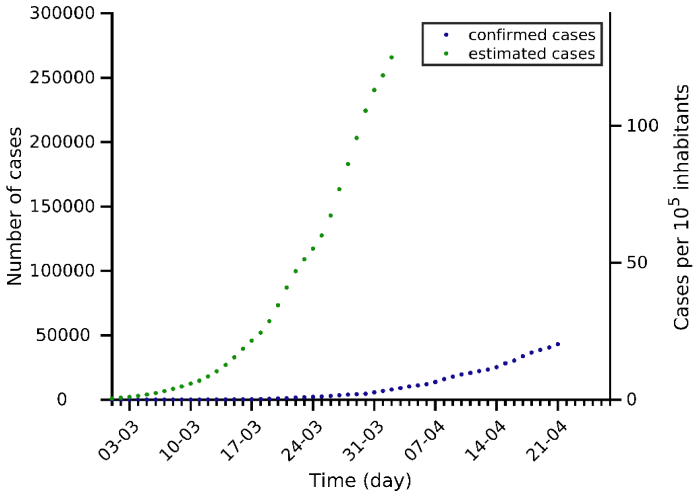


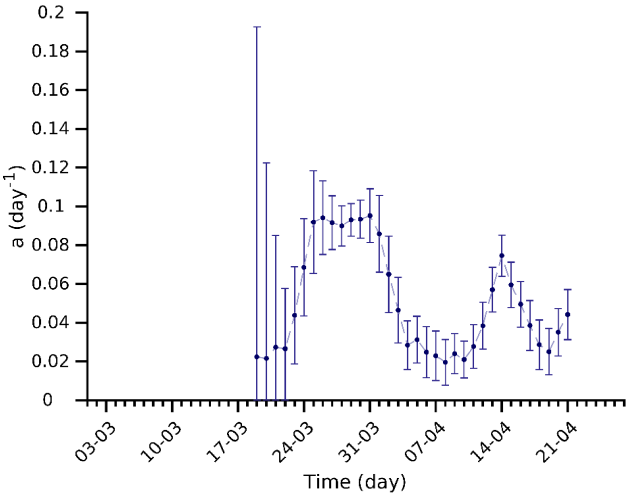


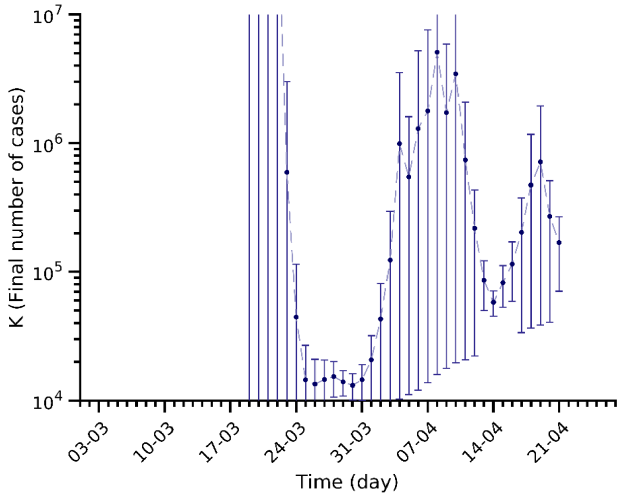


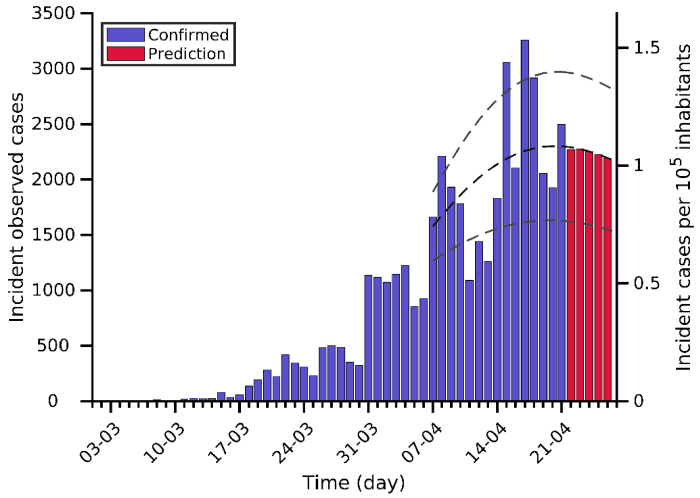
Brazil 21-04-2020. Population: 212.6M. Current cumulated incidence: $20/10^5$

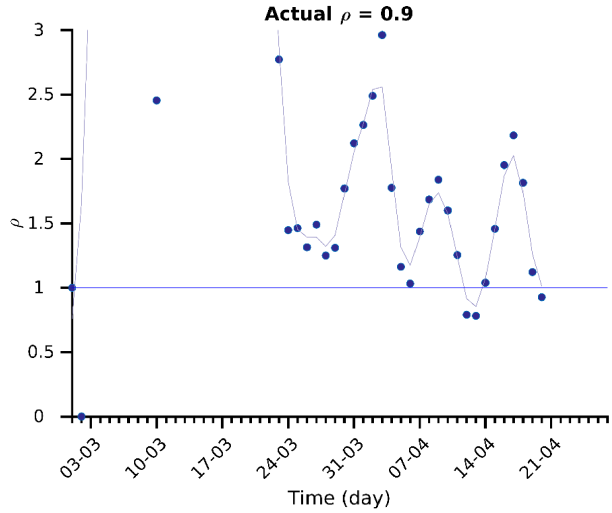


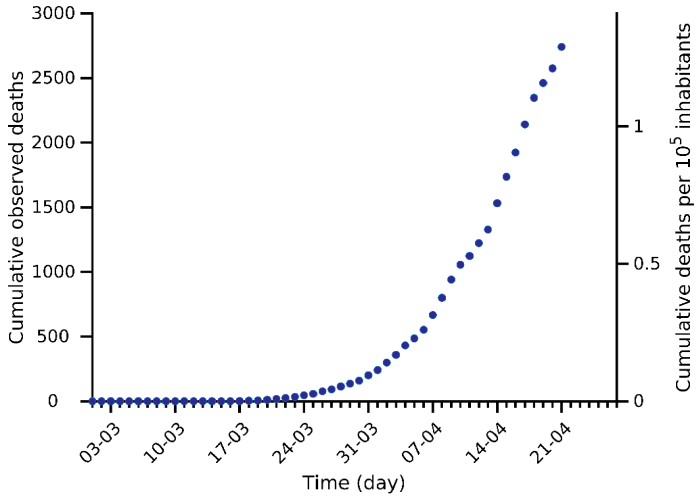


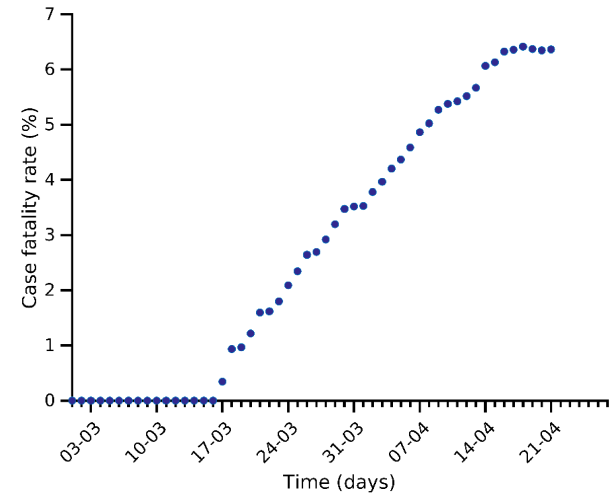




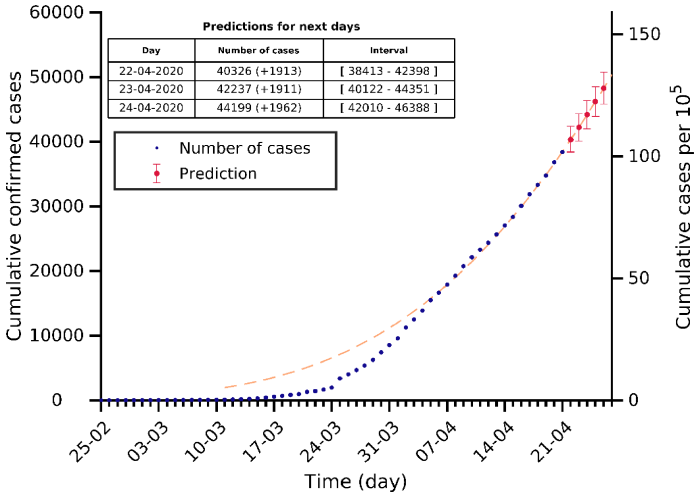


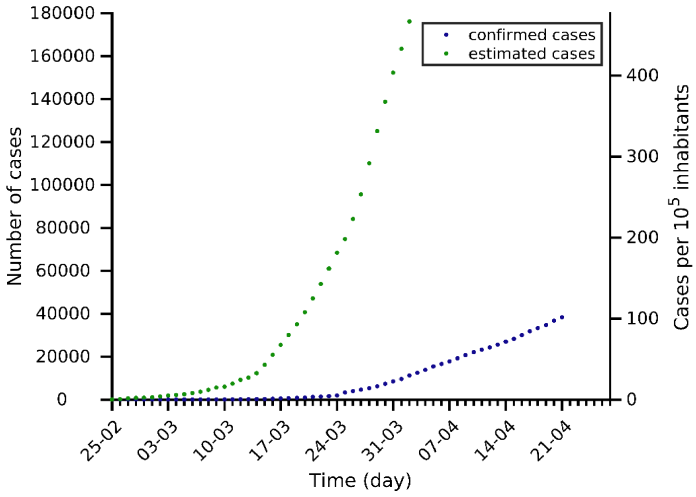


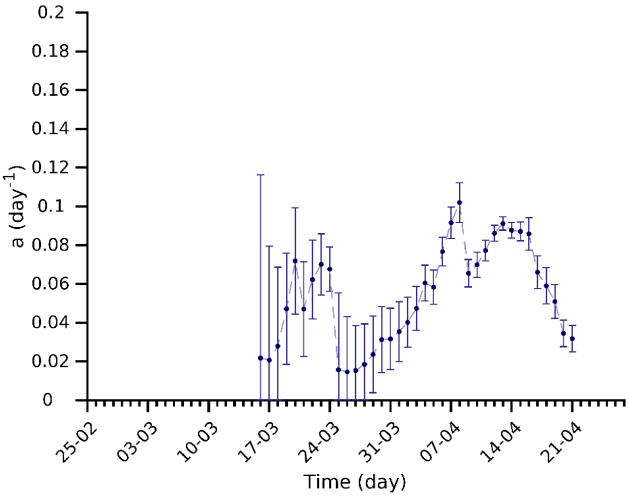


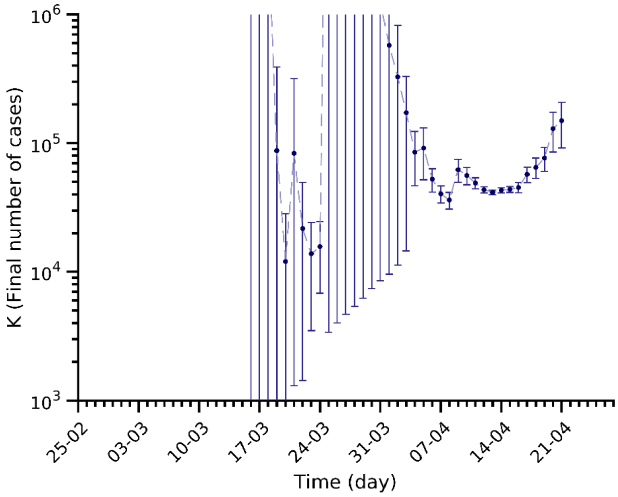


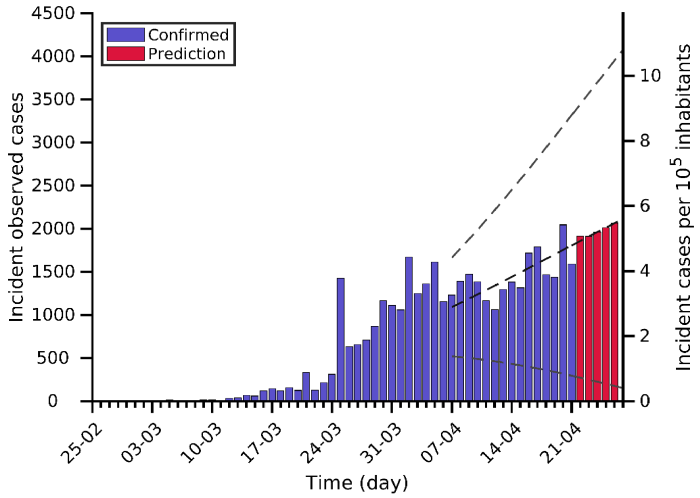
Canada 21-04-2020. Population: 37.7M. Current cumulated incidence: 102/10⁵

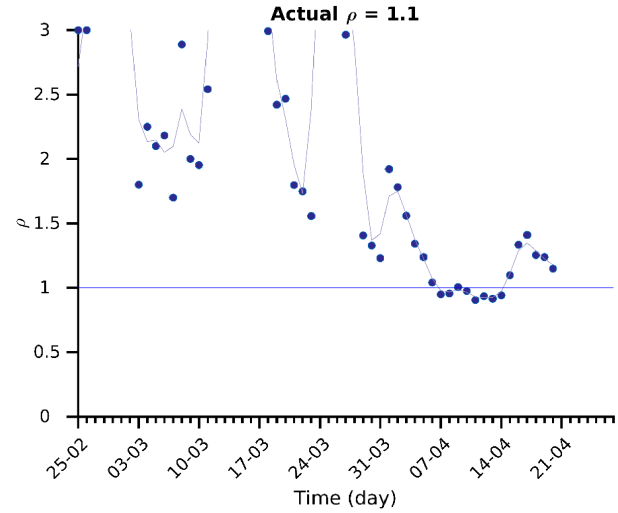


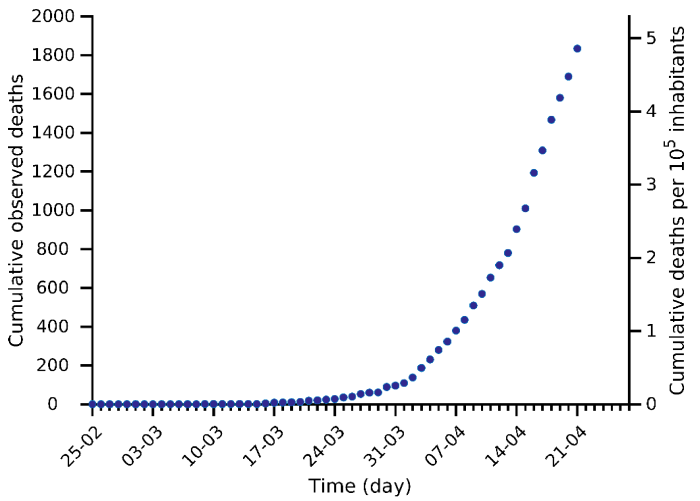


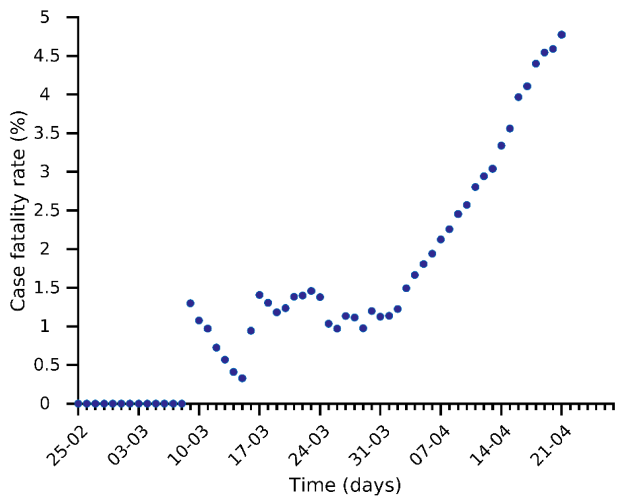




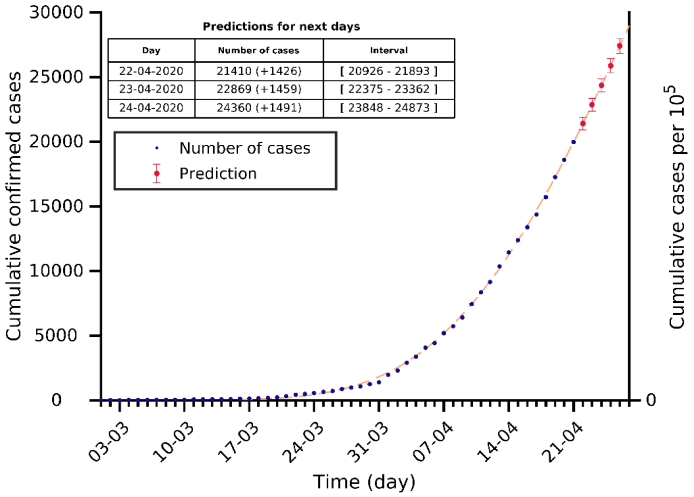


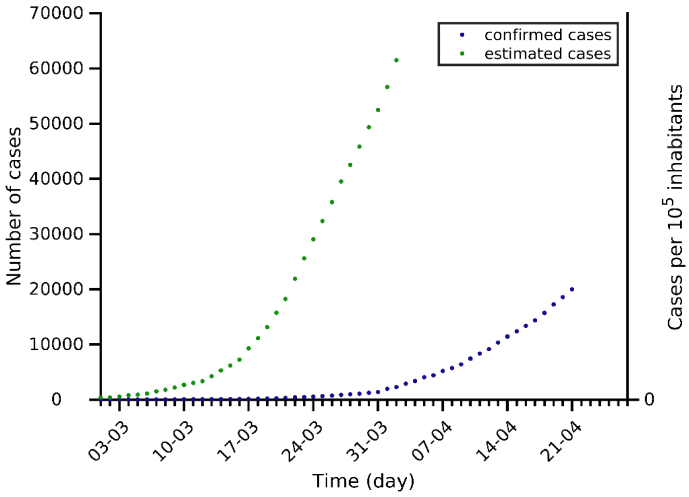


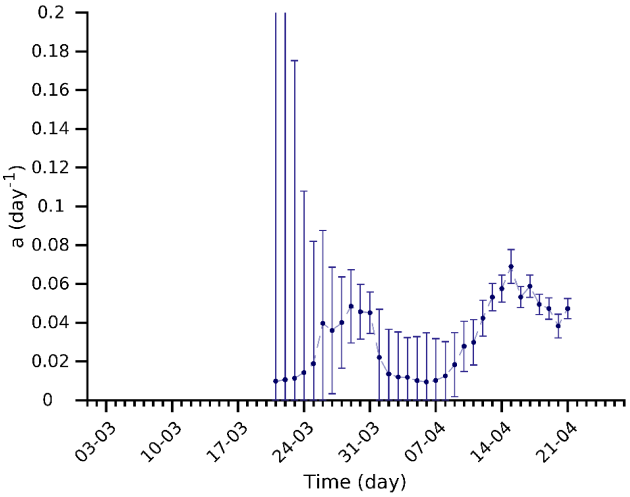


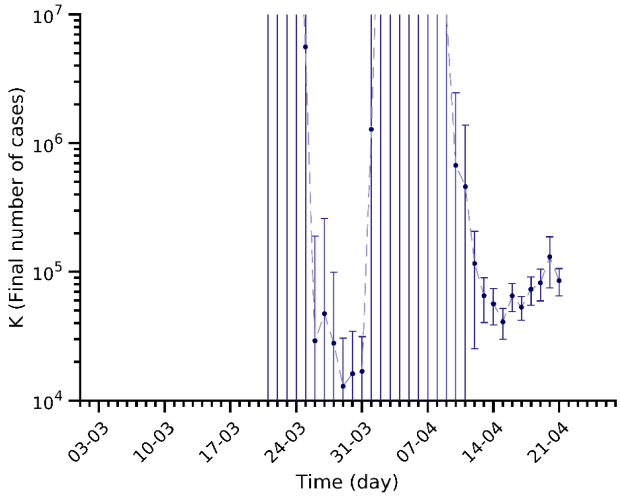


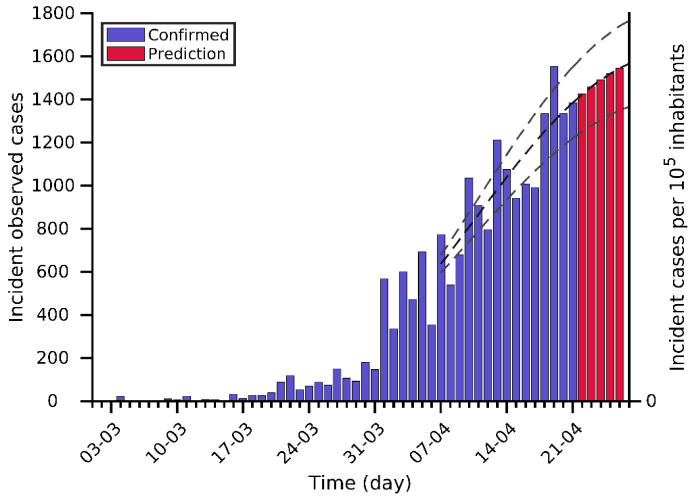
India 21-04-2020. Population: 1353000.0M. Current cumulated incidence: 0/10^5

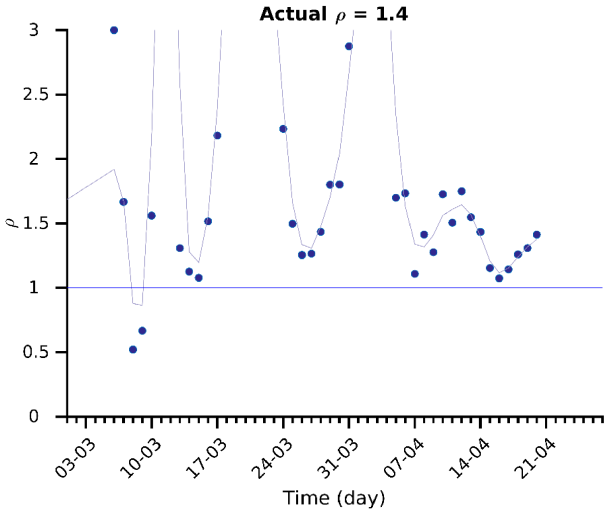


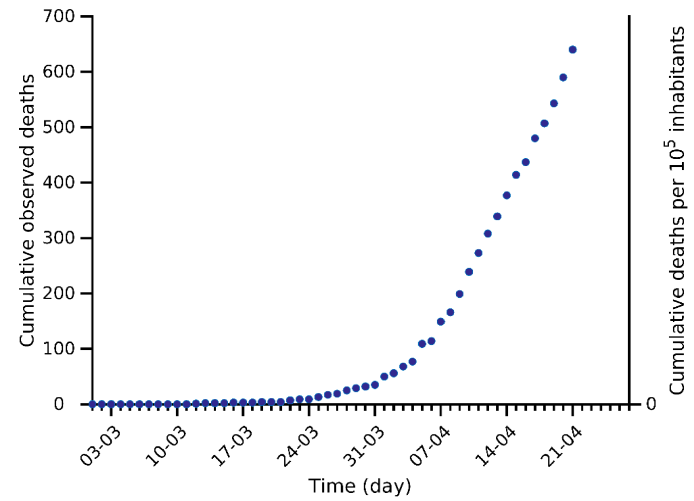


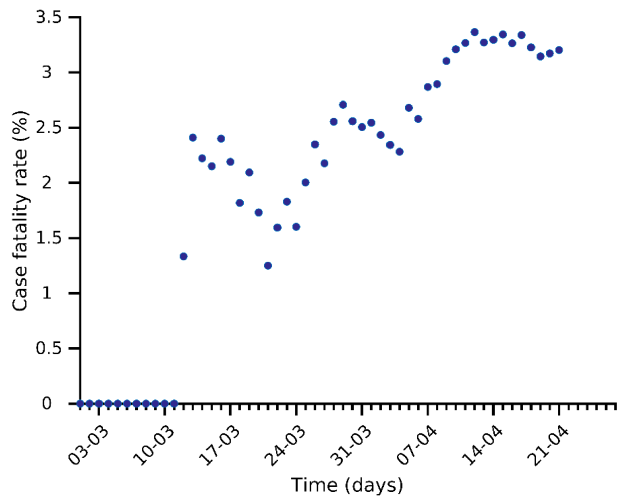




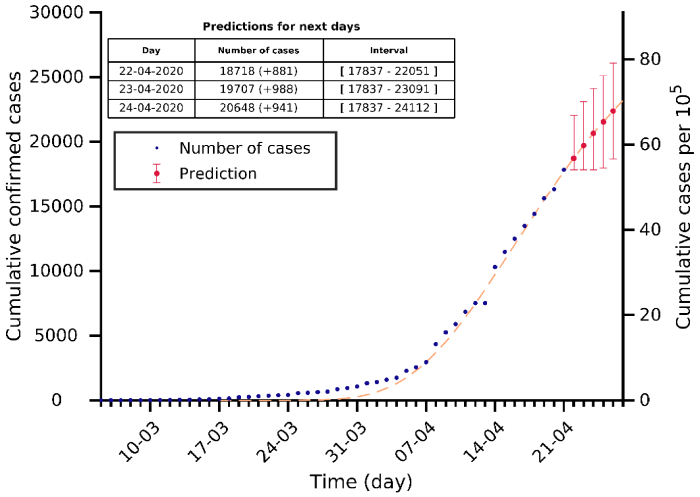


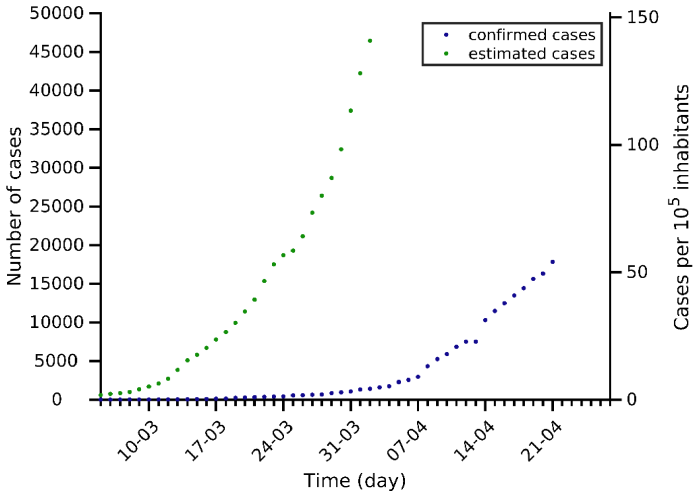


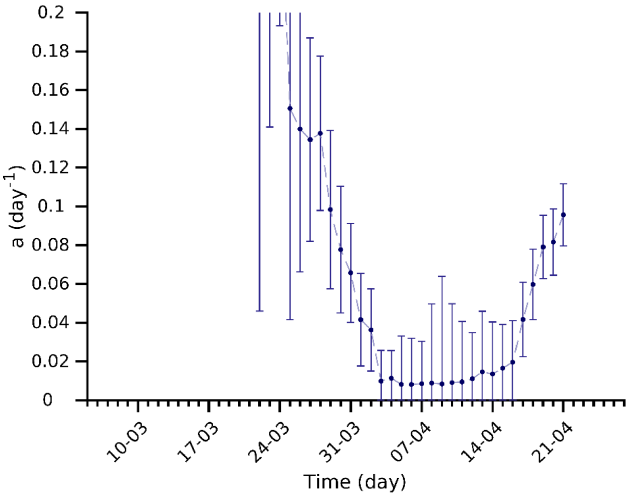


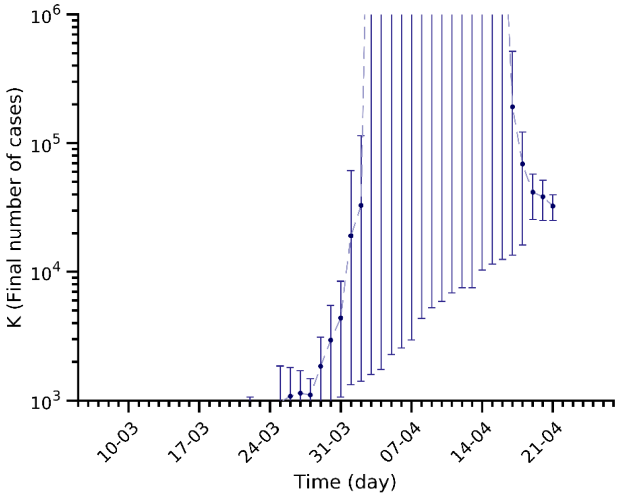


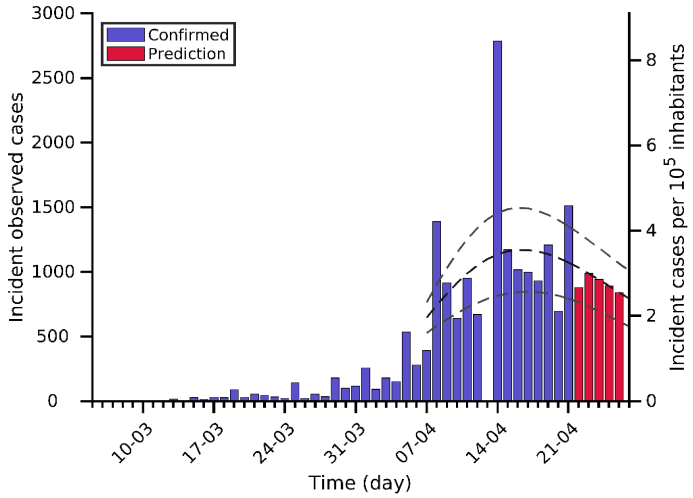
Peru 21-04-2020. Population: 33.0M. Current cumulated incidence: $54/10^5$

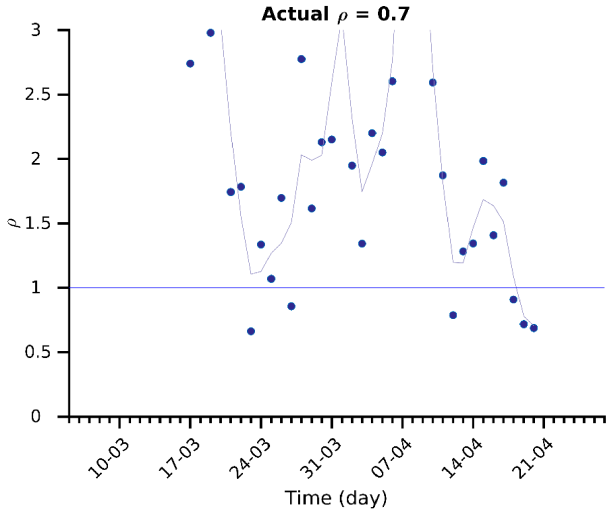


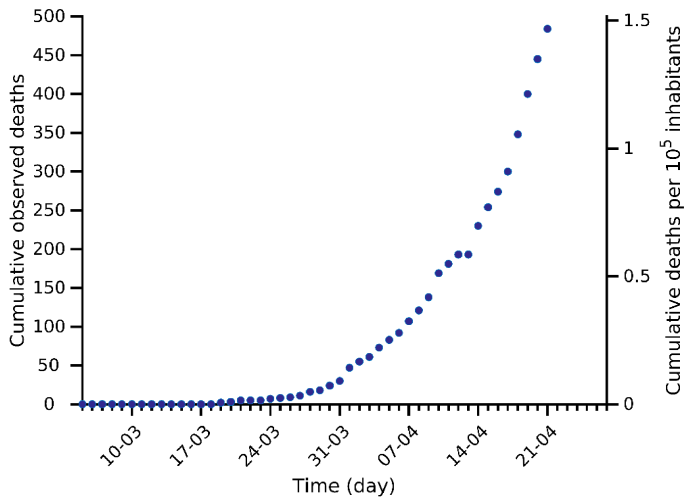


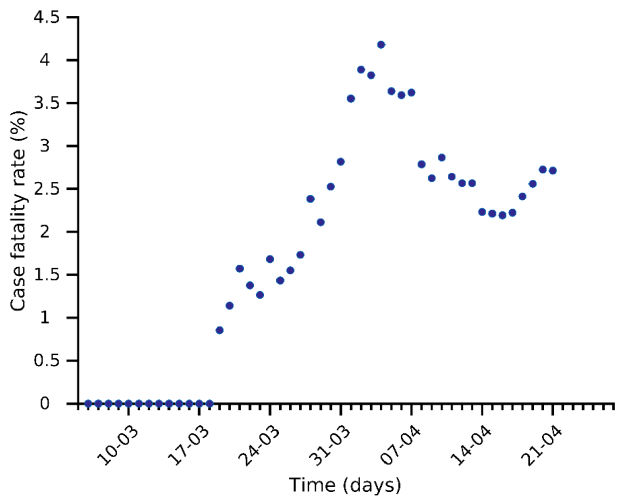




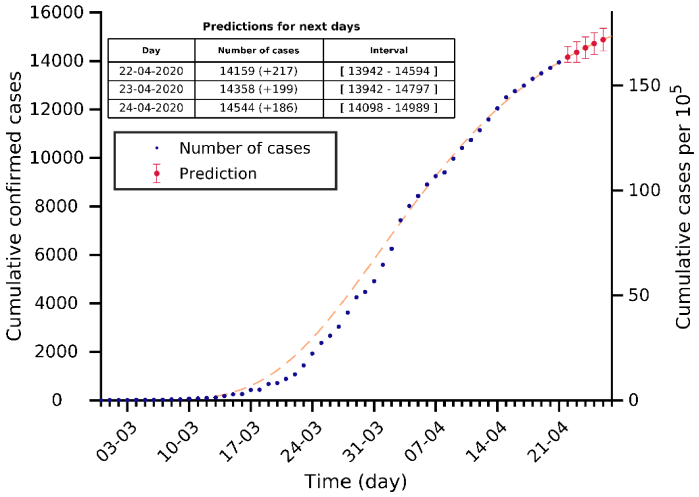


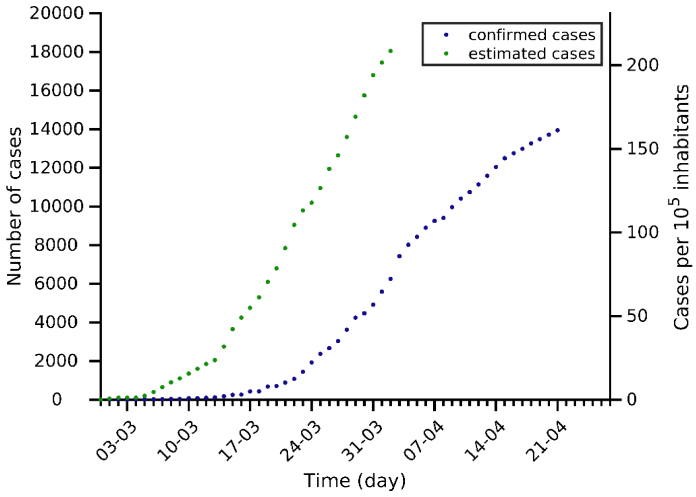


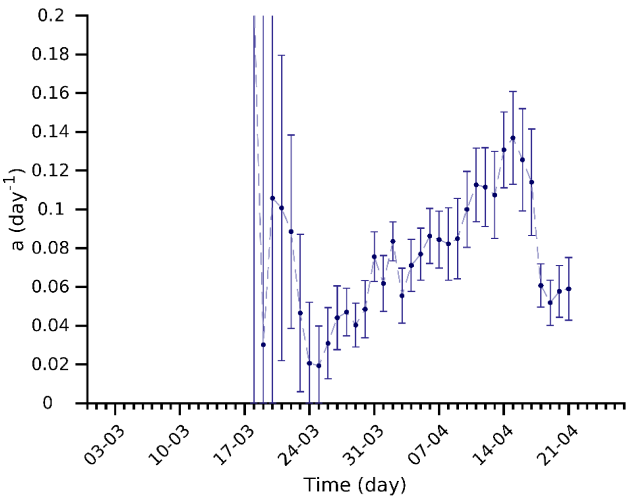


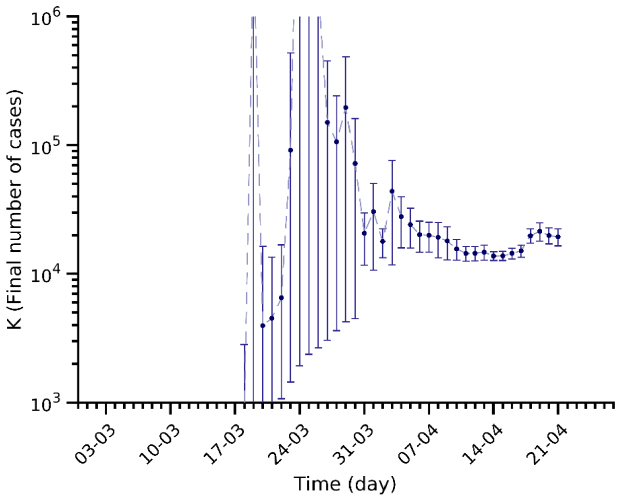


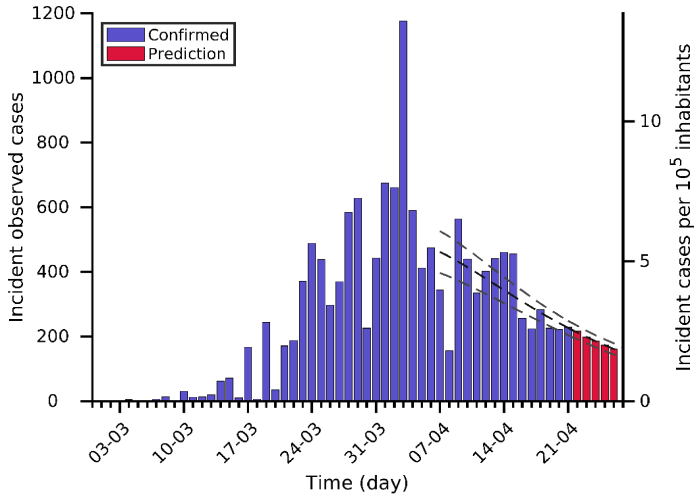
Israel 21-04-2020. Population: 8.7M. Current cumulated incidence: $161/10^5$

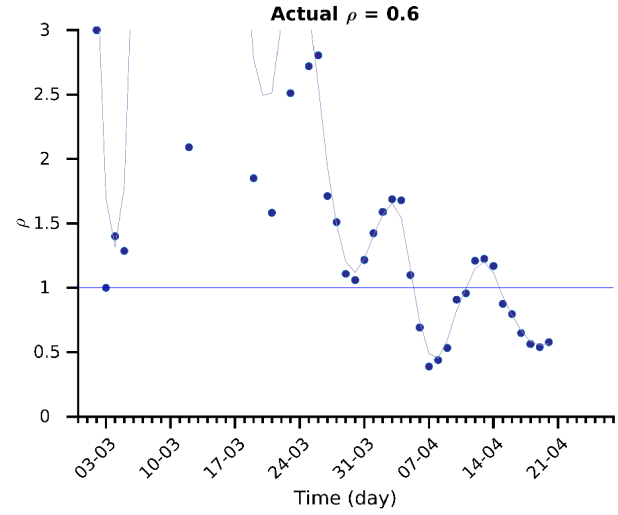


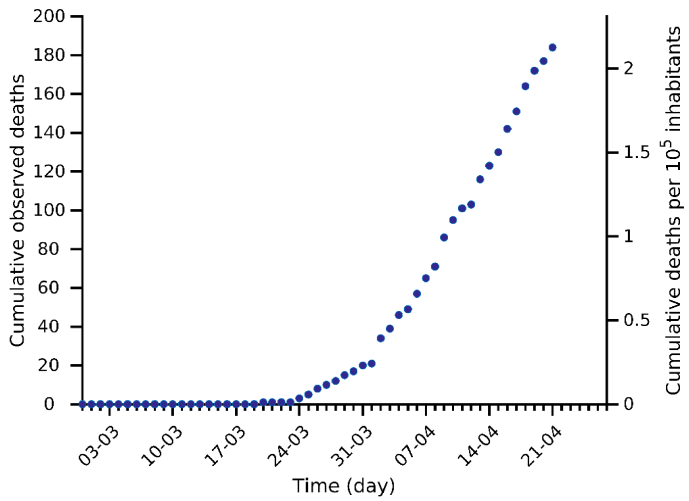


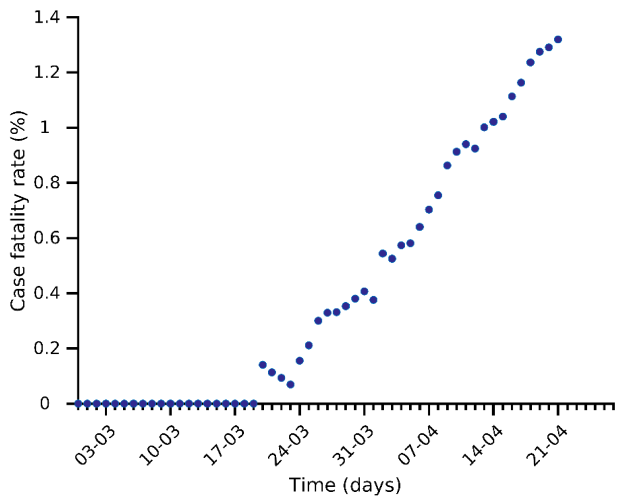




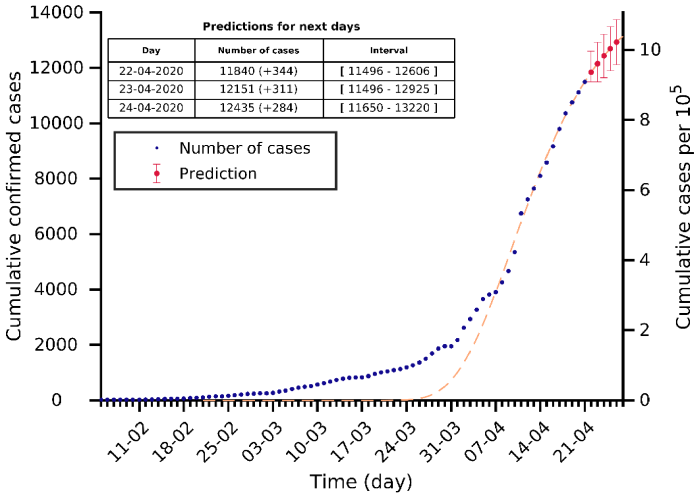


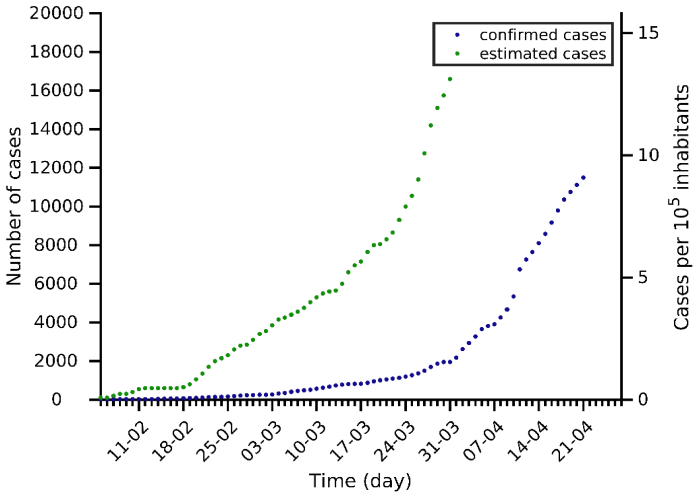


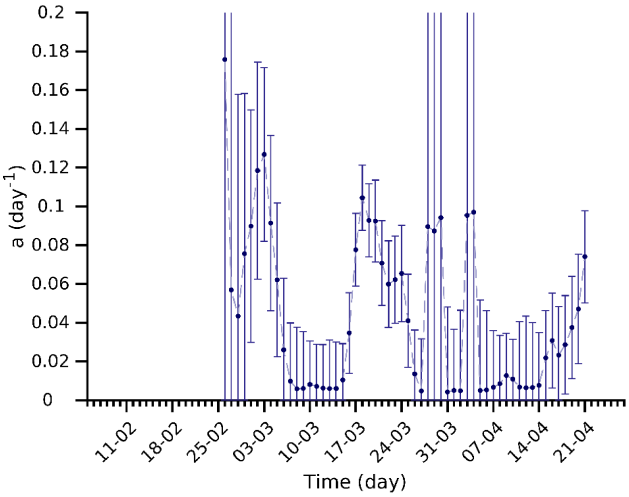


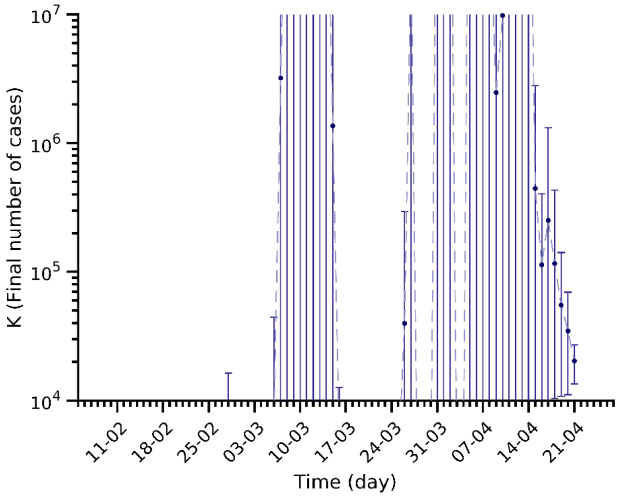


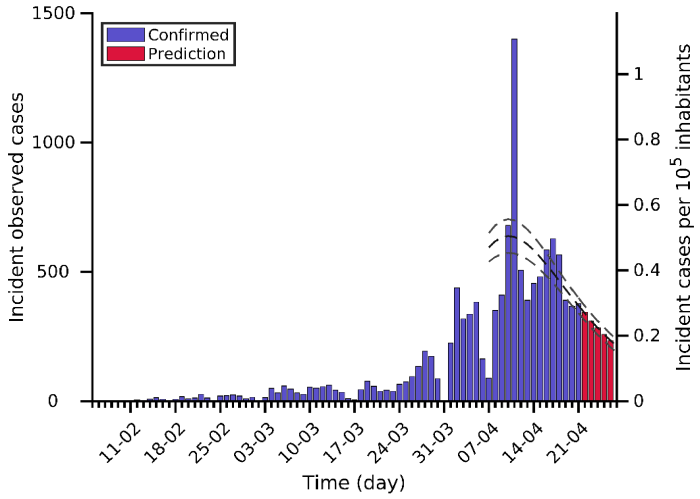
Japan 21-04-2020. Population: 126.5M. Current cumulated incidence: $9/10^5$

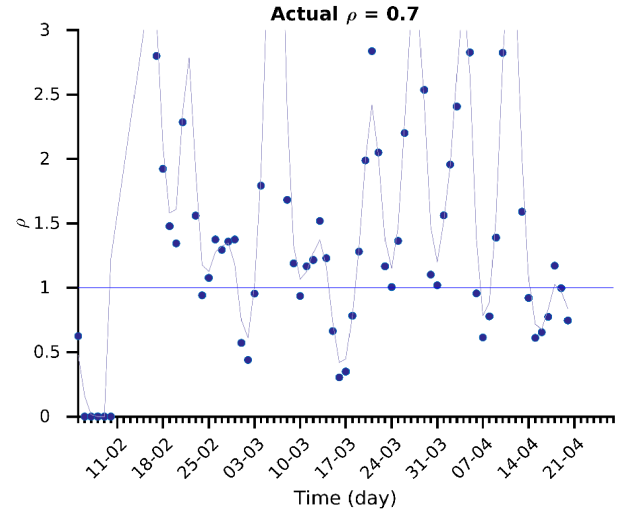


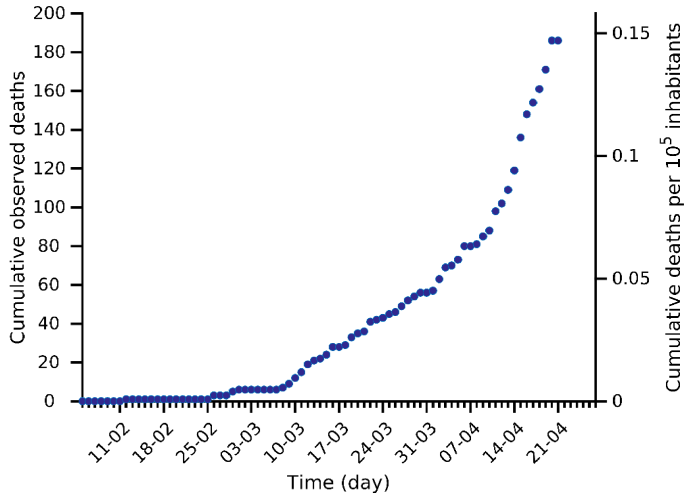


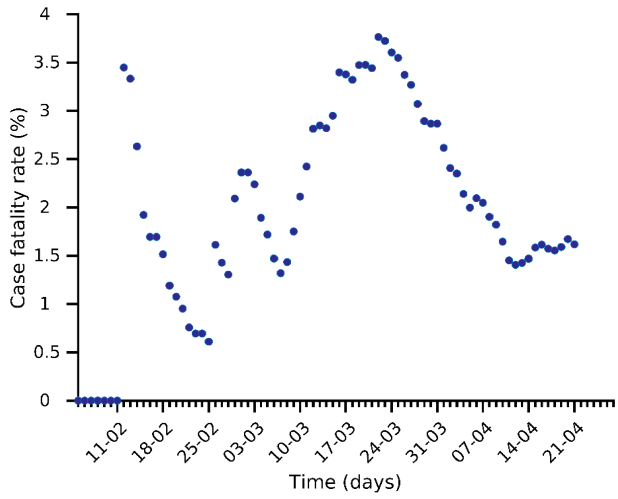




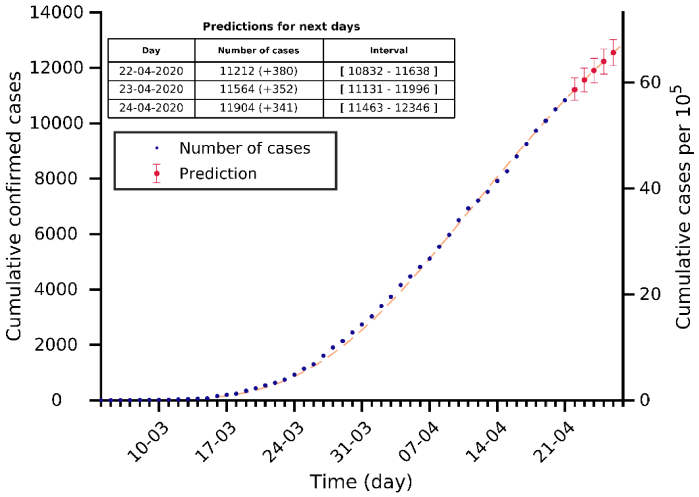


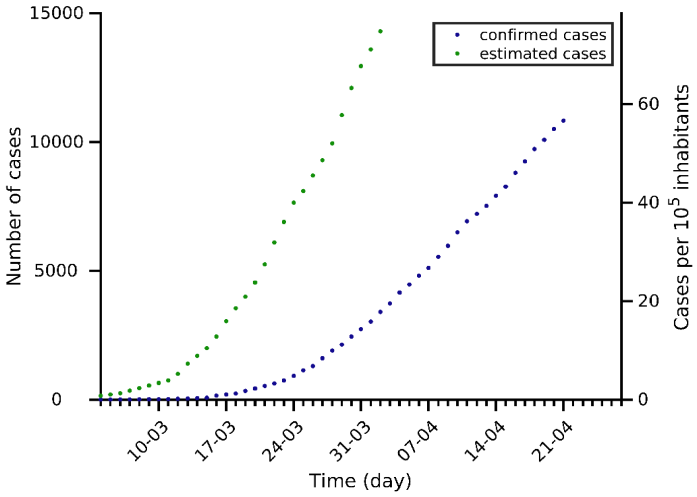


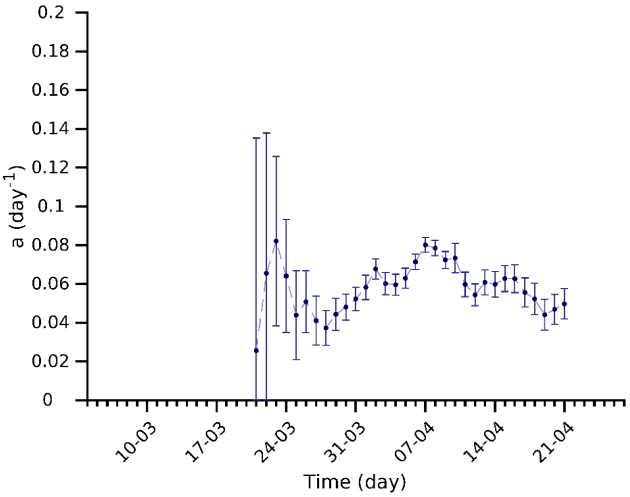


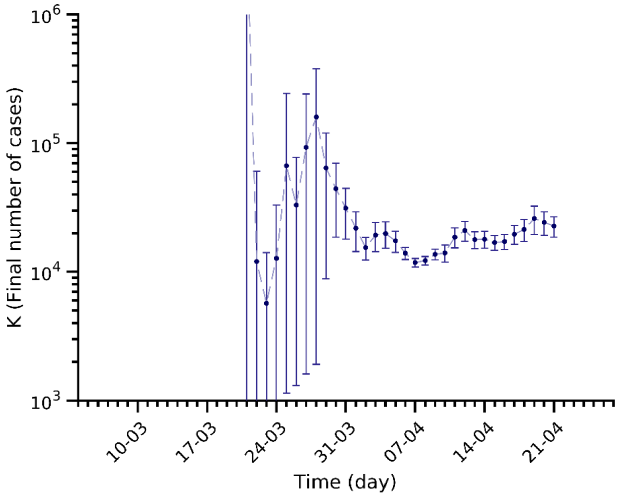


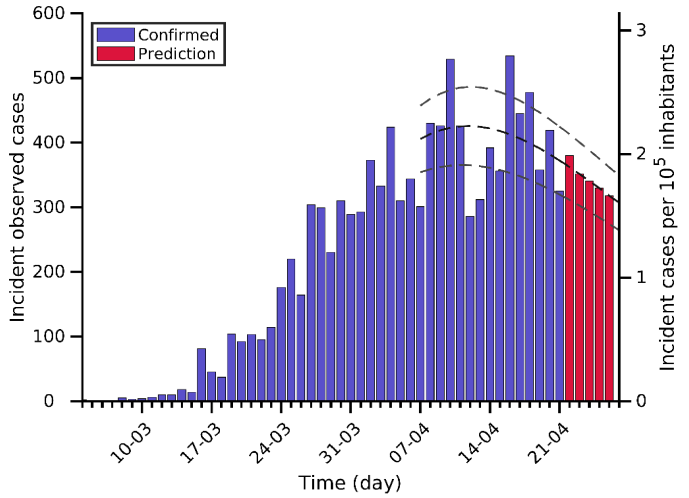
Chile 21-04-2020. Population: 19.1M. Current cumulated incidence: 57/10^5

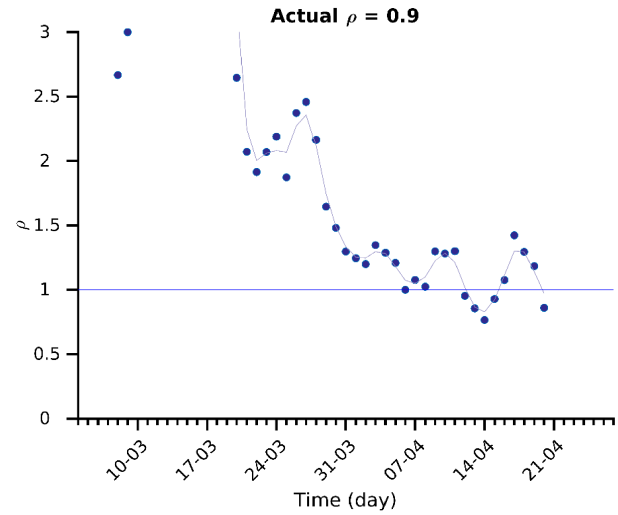


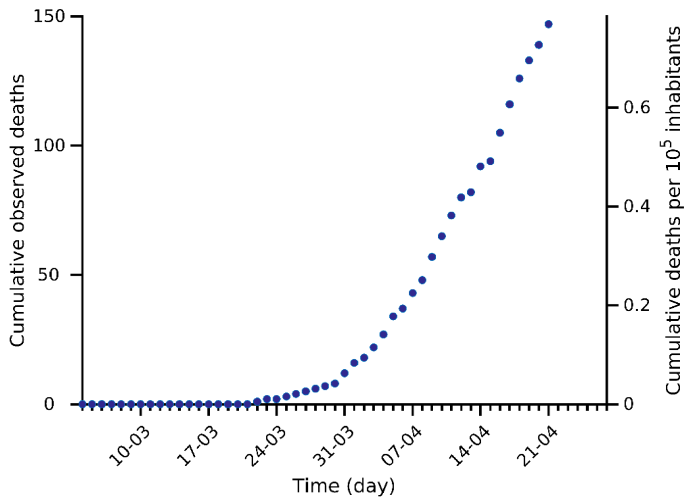


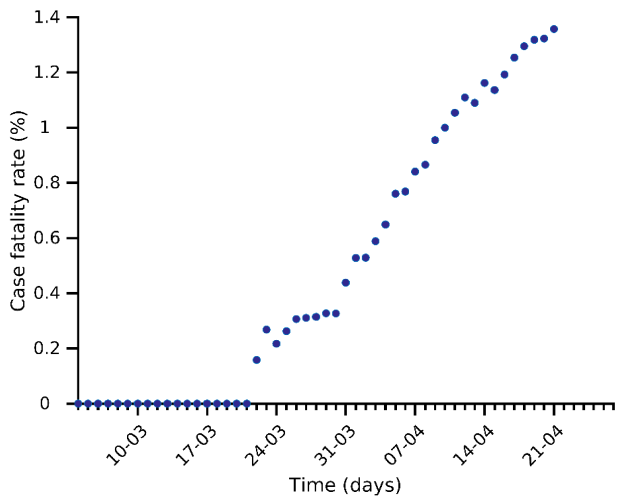




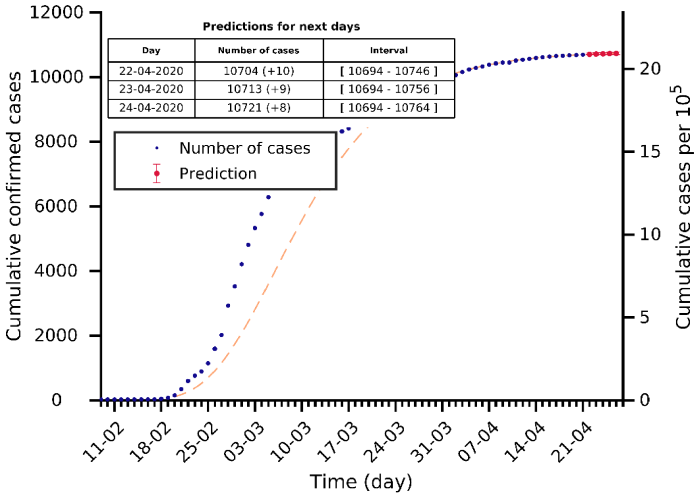


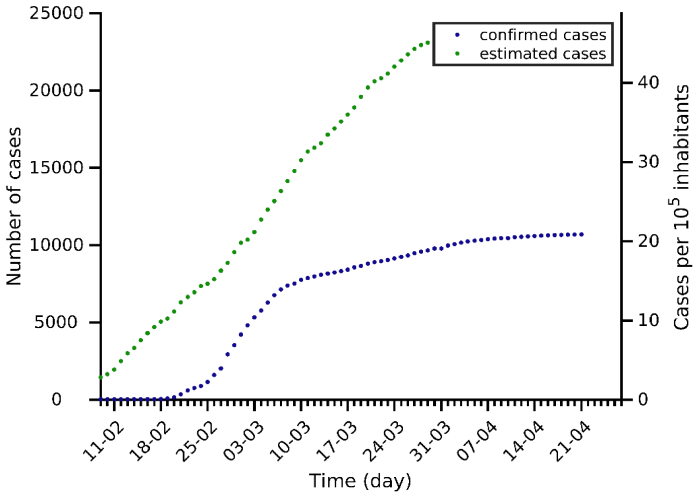


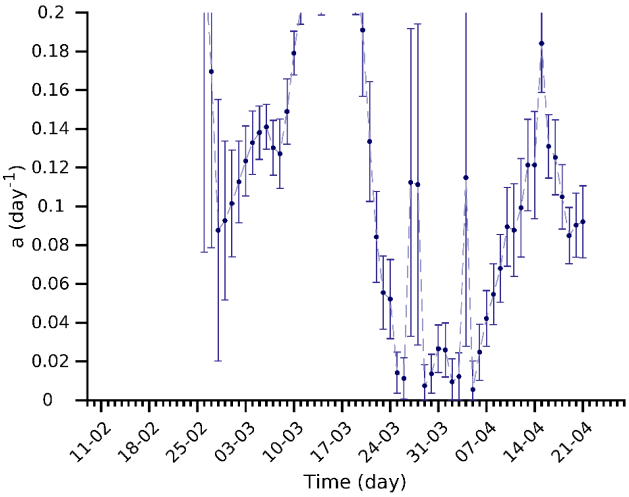


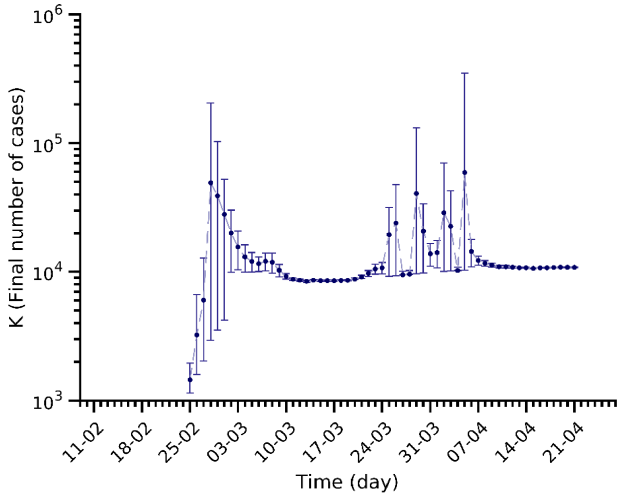


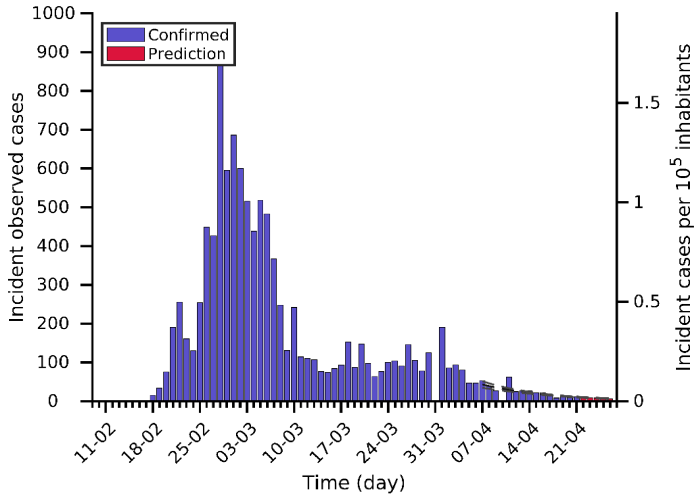
South Korea 21-04-2020. Population: 51.3M. Current cumulated incidence: $21/10^5$

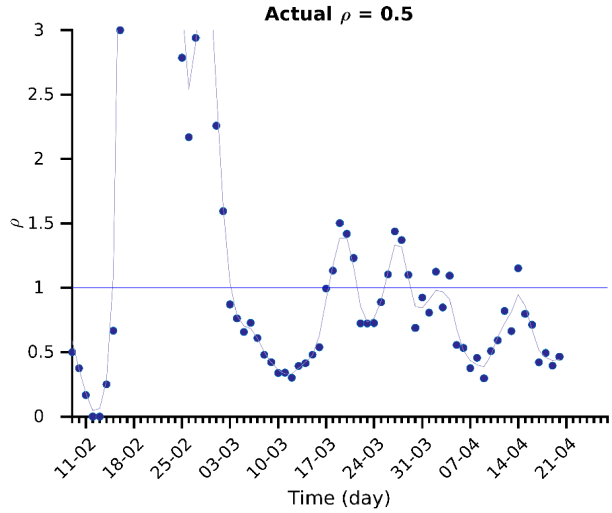


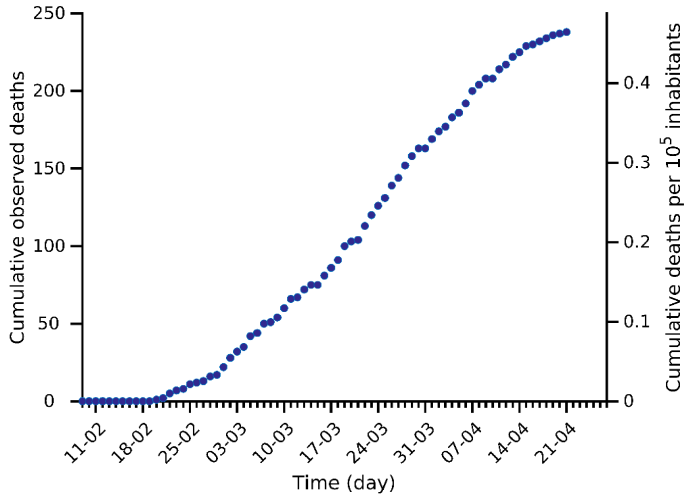


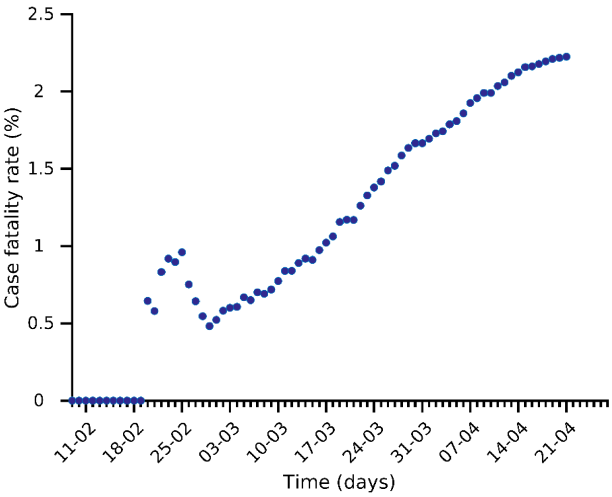




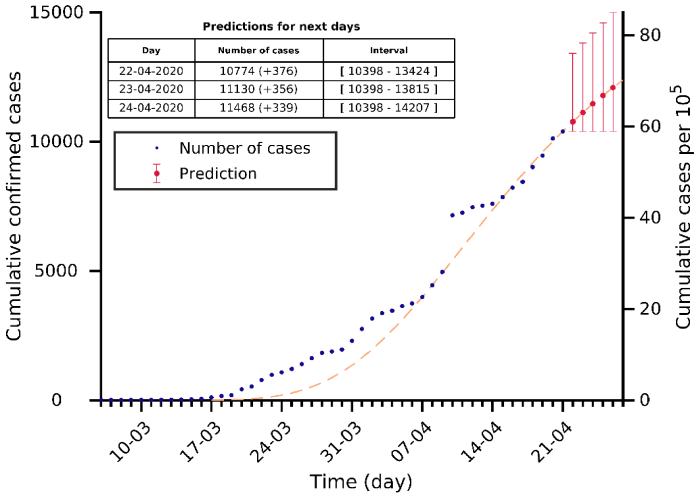


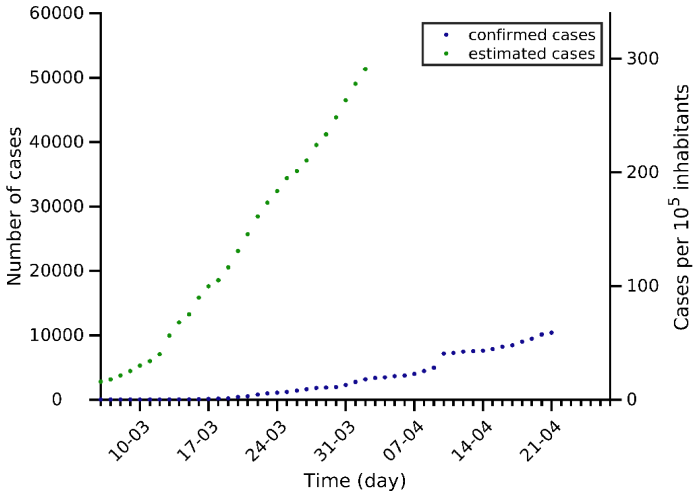


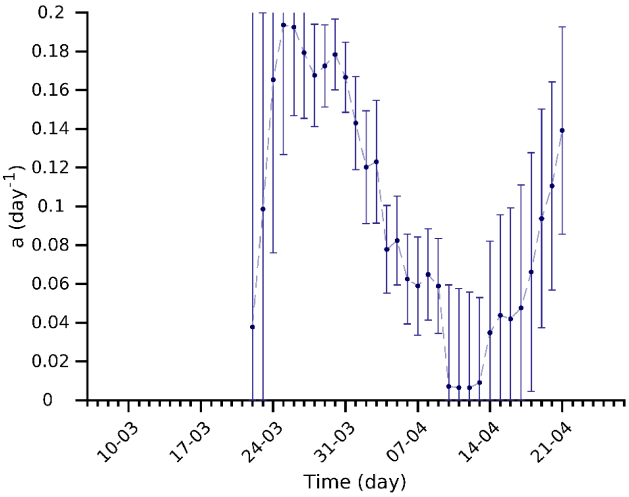


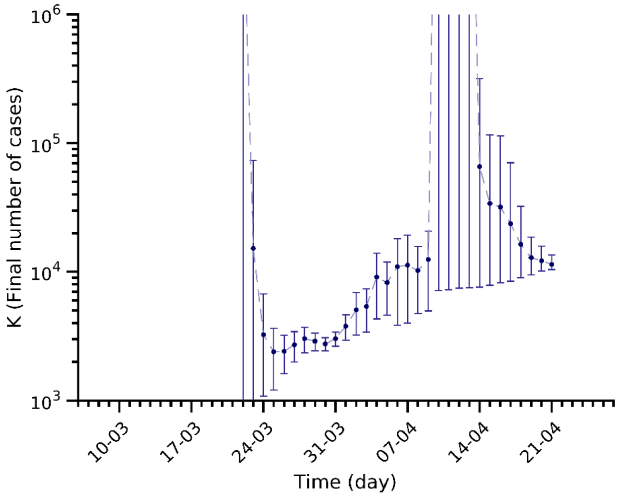


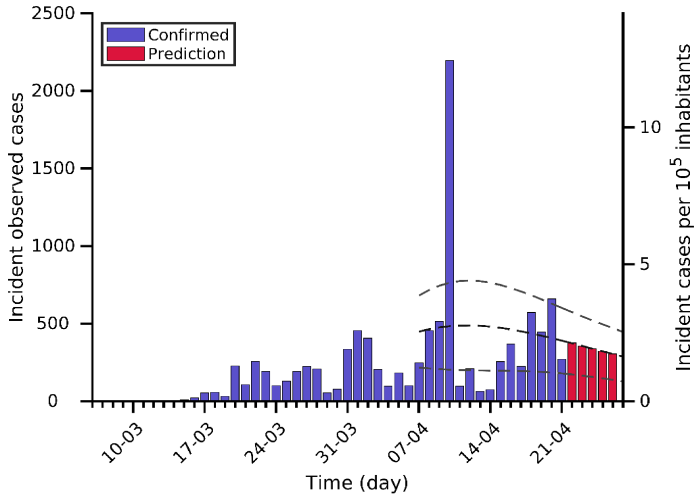
Ecuador 21-04-2020. Population: 17.6M. Current cumulated incidence: 59/10^5

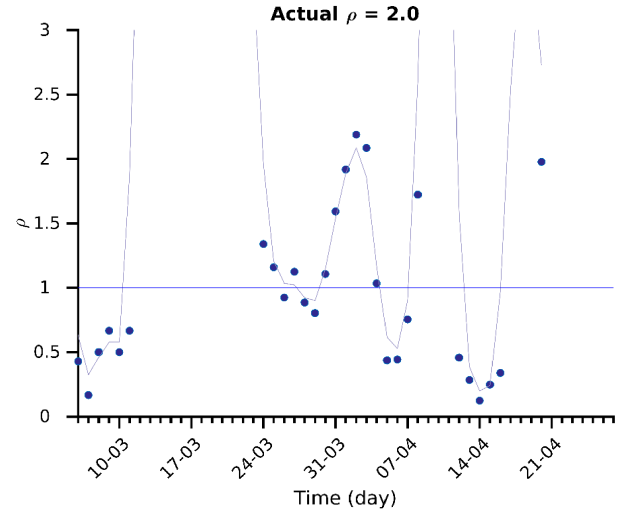


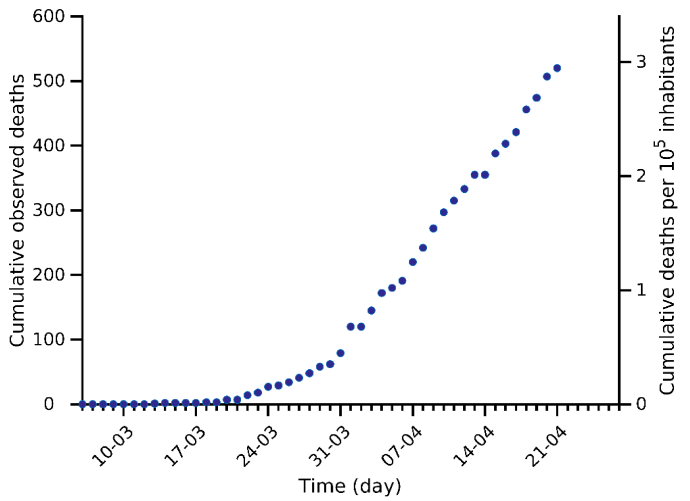


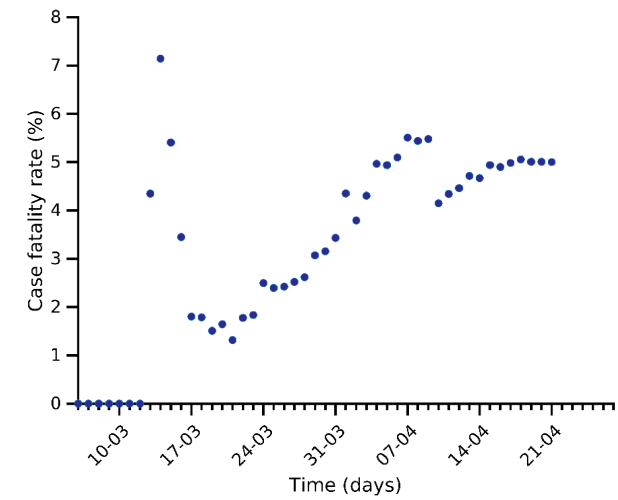




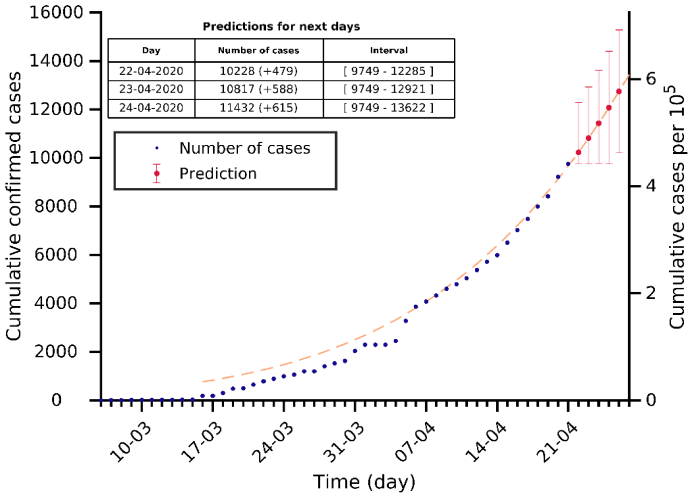


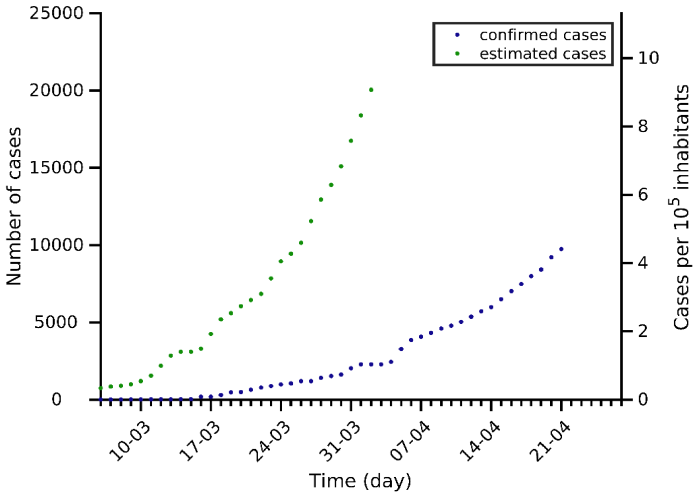


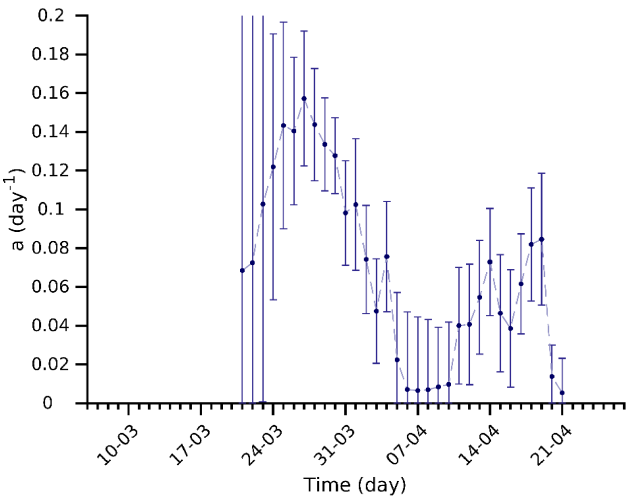


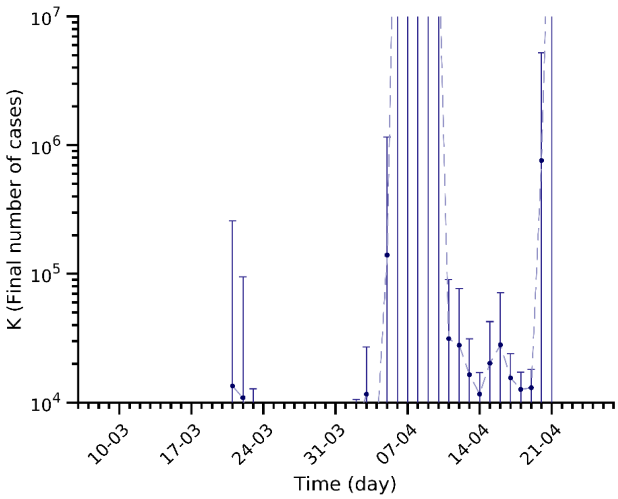


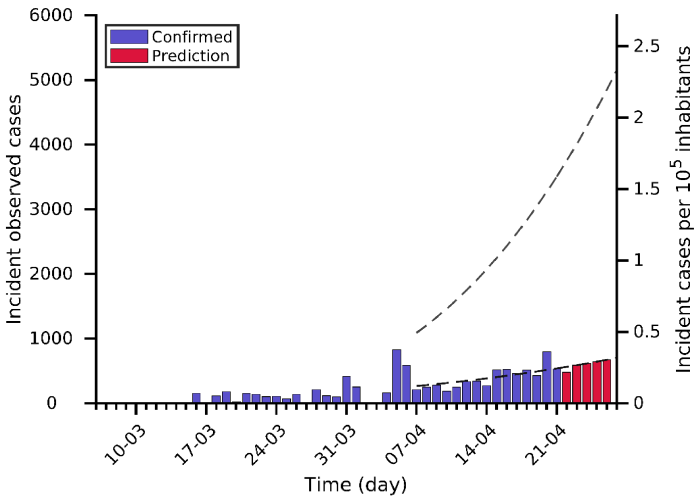
Pakistan 21-04-2020. Population: 220.9M. Current cumulated incidence: 4/10⁵

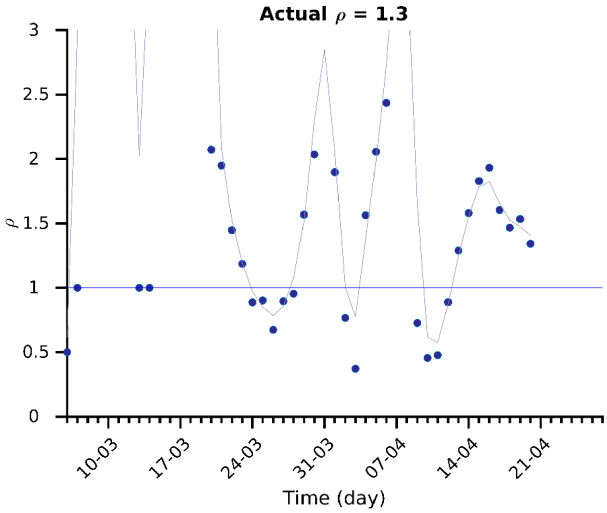


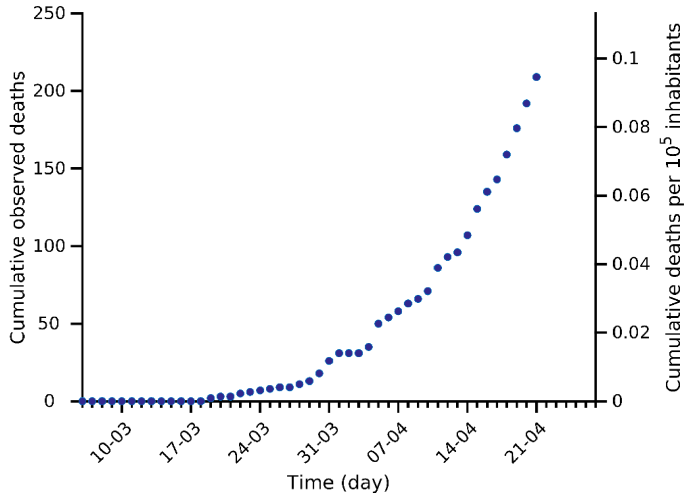


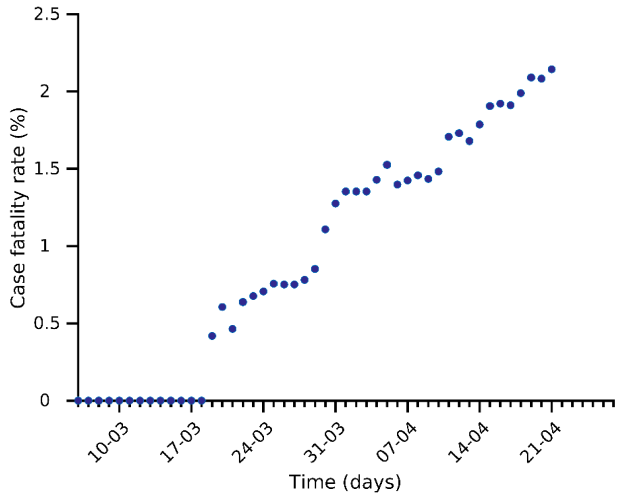




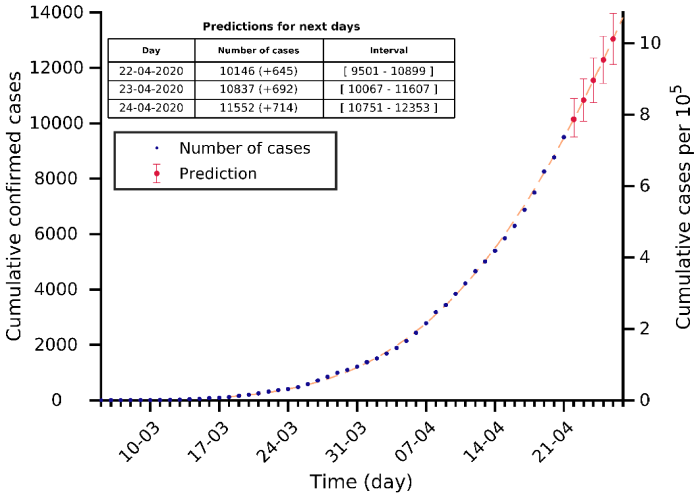


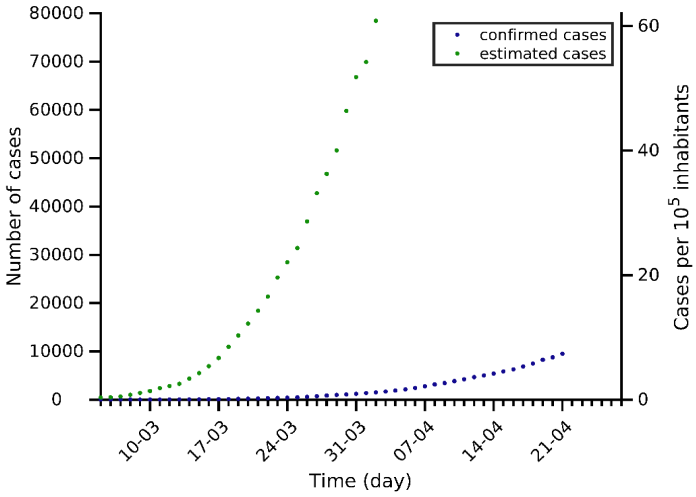


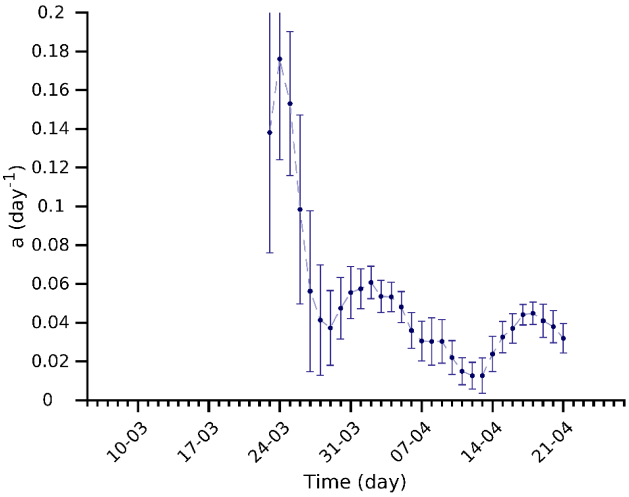


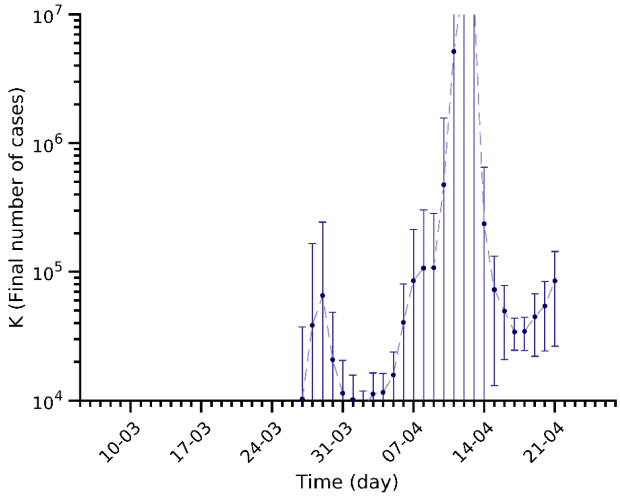


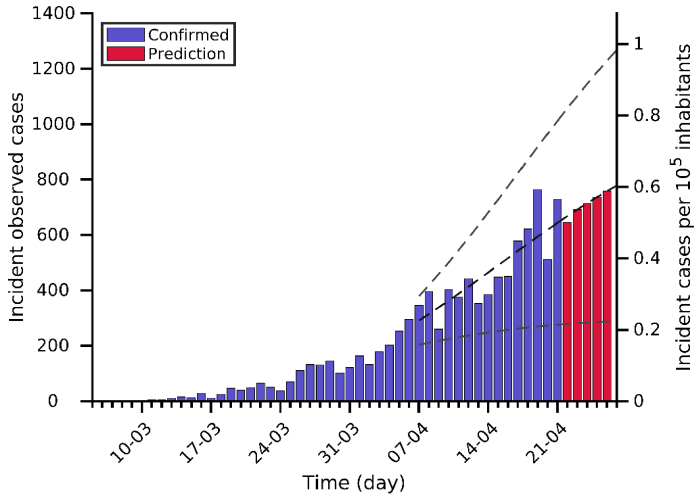
Mexico 21-04-2020. Population: 128.9M. Current cumulated incidence: $7/10^5$

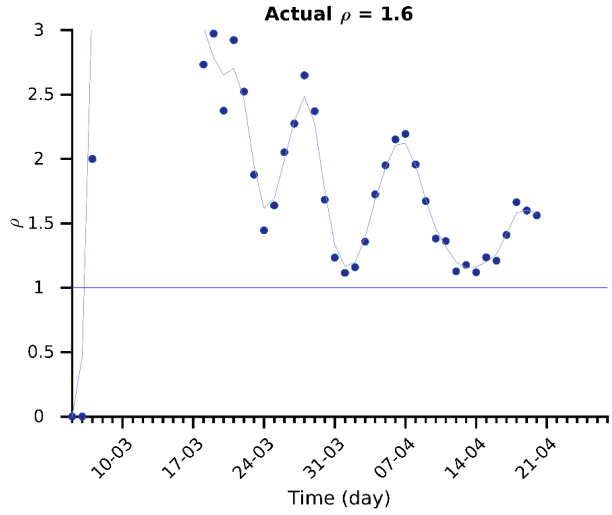


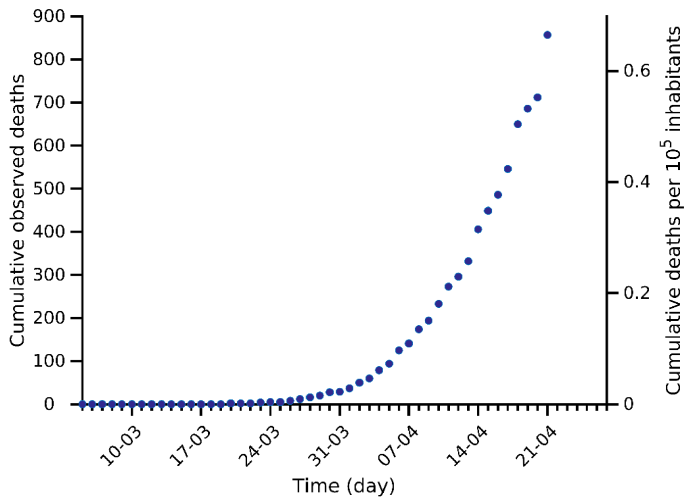


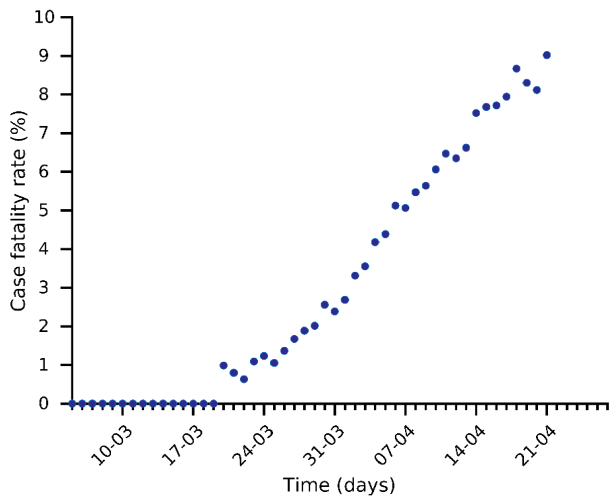




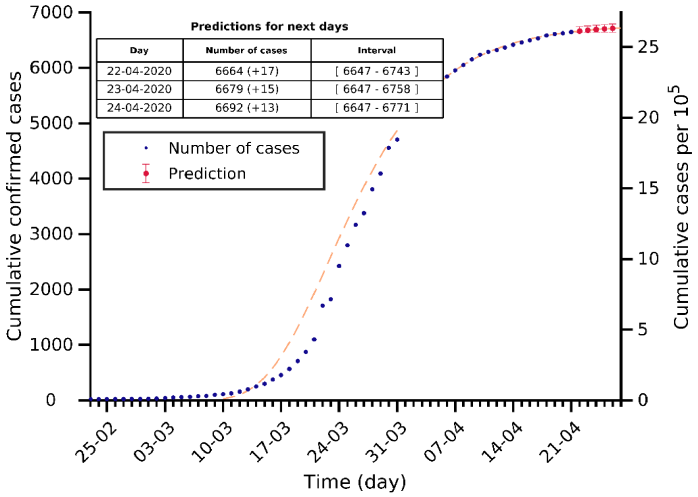


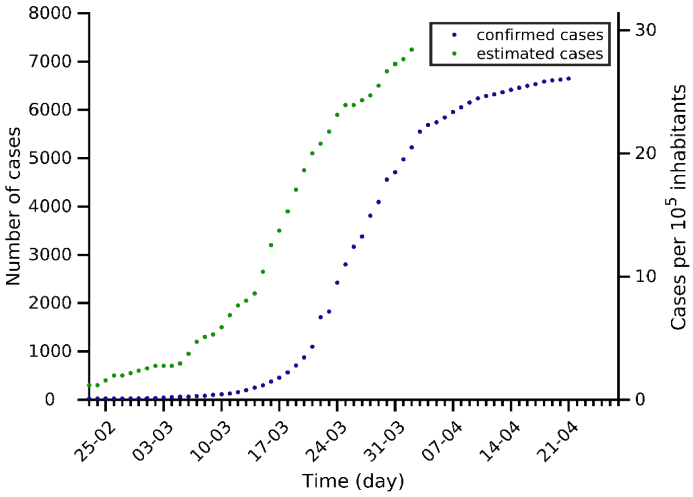


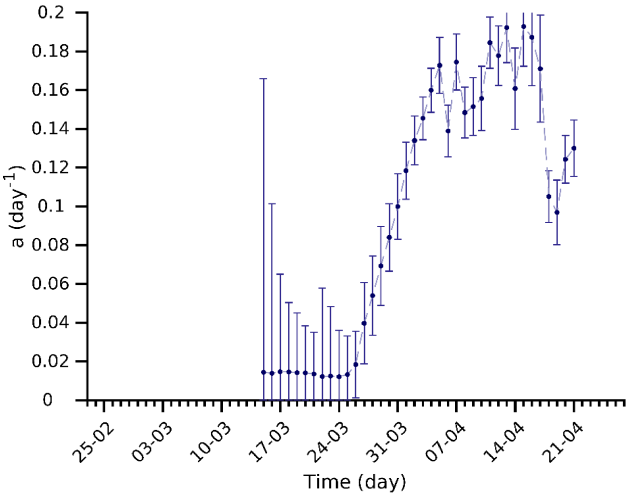


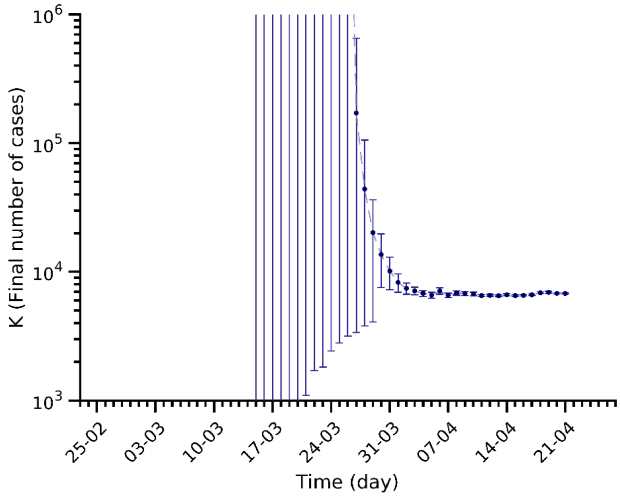


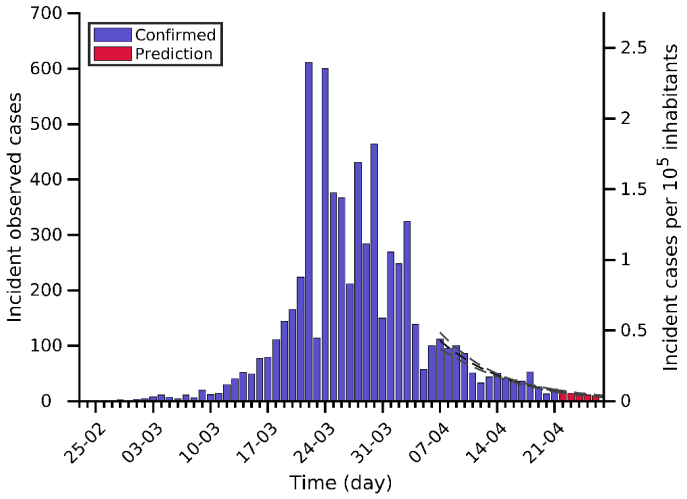
Australia 21-04-2020. Population: 25.5M. Current cumulated incidence: 26/10⁵

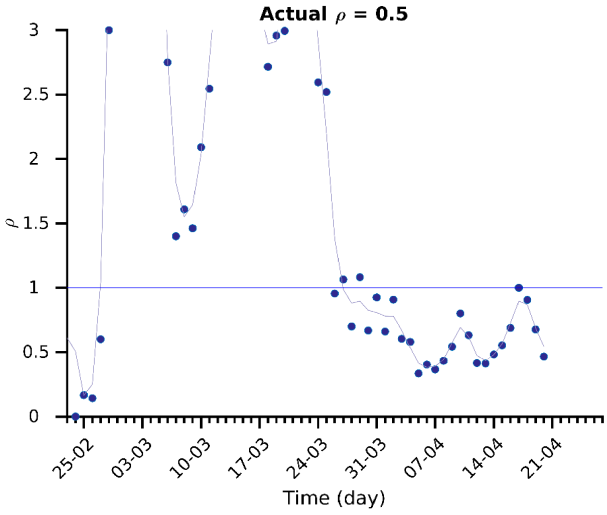


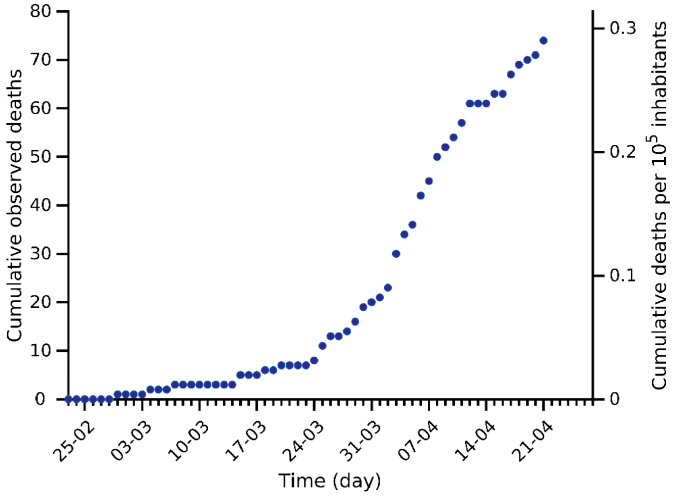


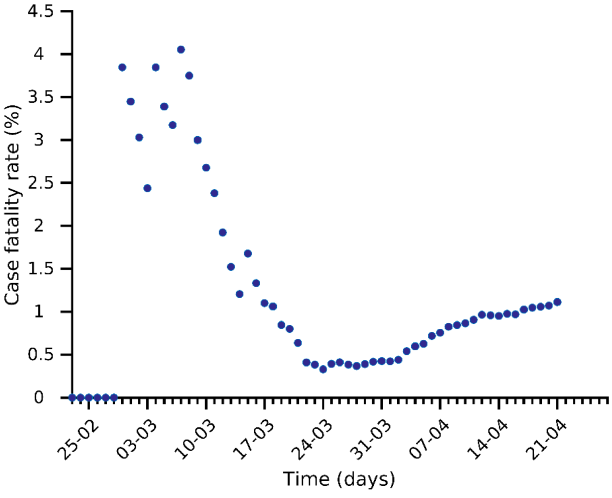




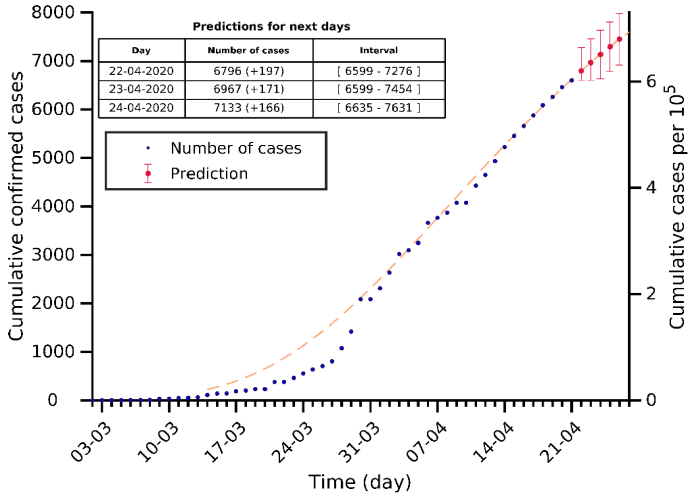


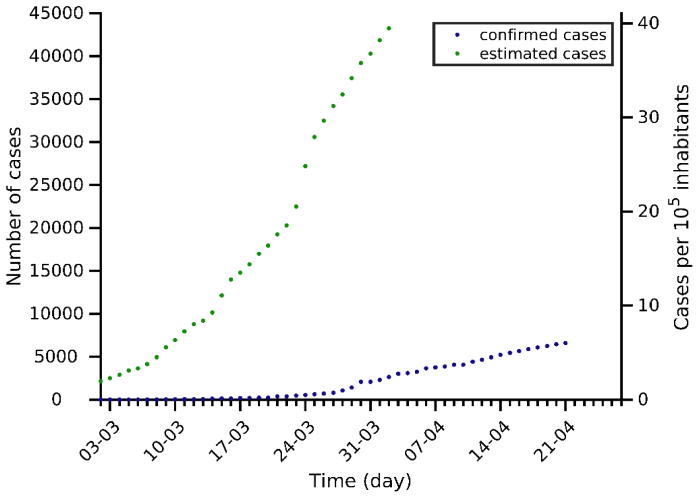


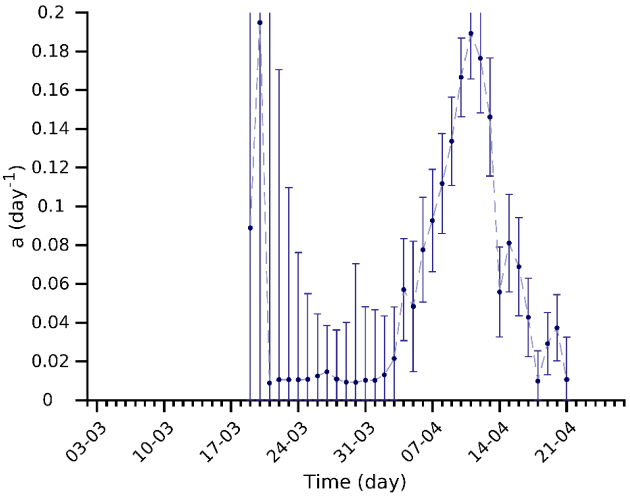


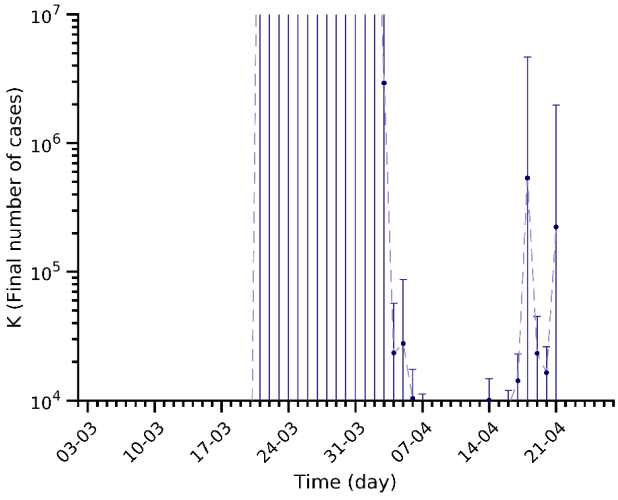


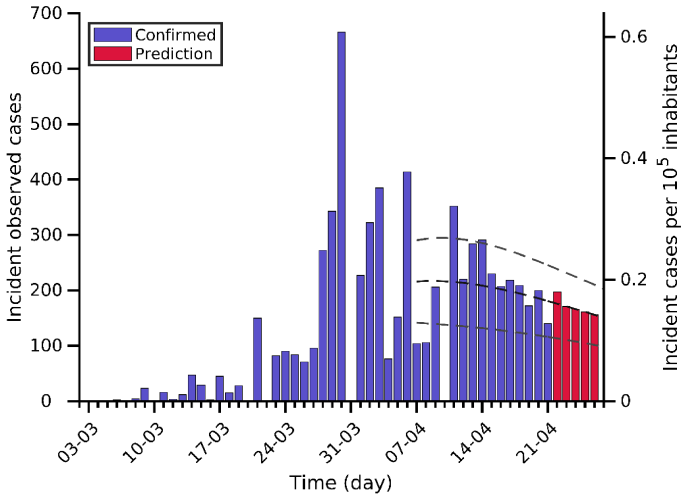
Philippines 21-04-2020. Population: 109.6M. Current cumulated incidence: $6/10^5$

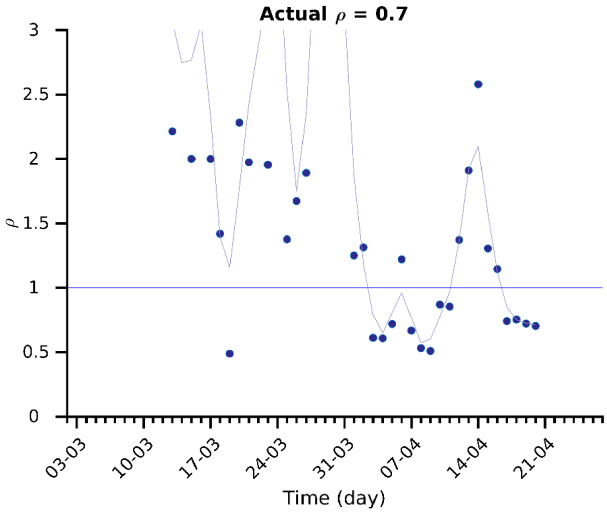


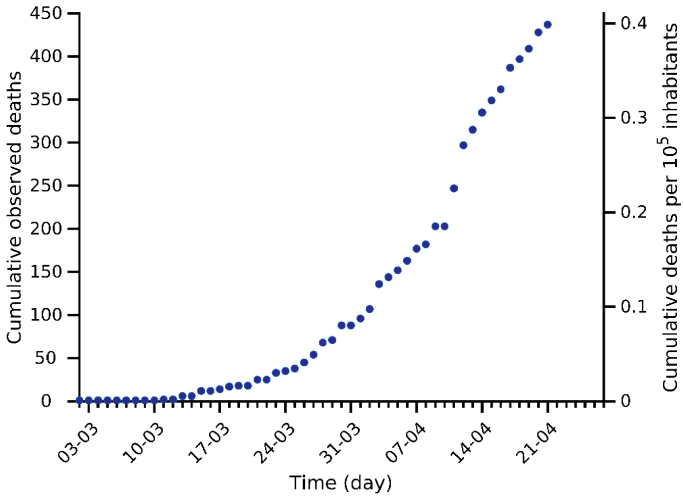


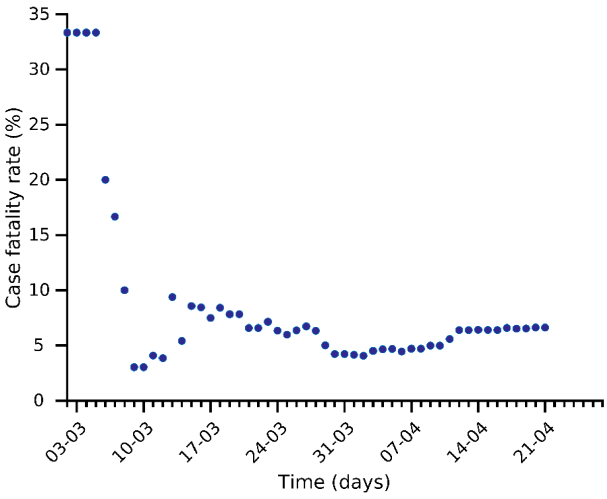




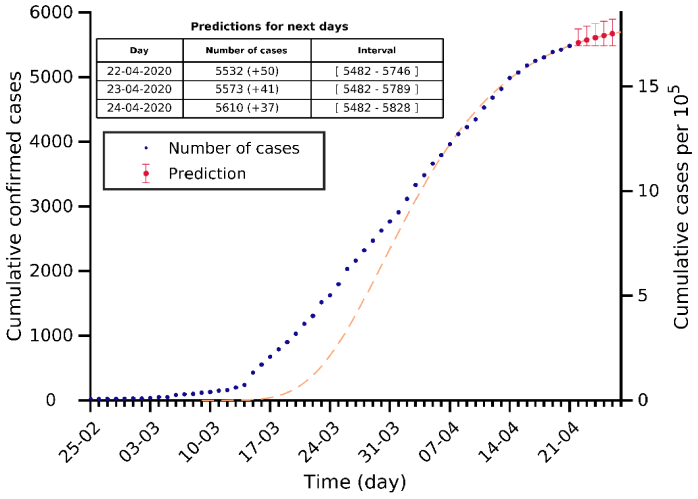


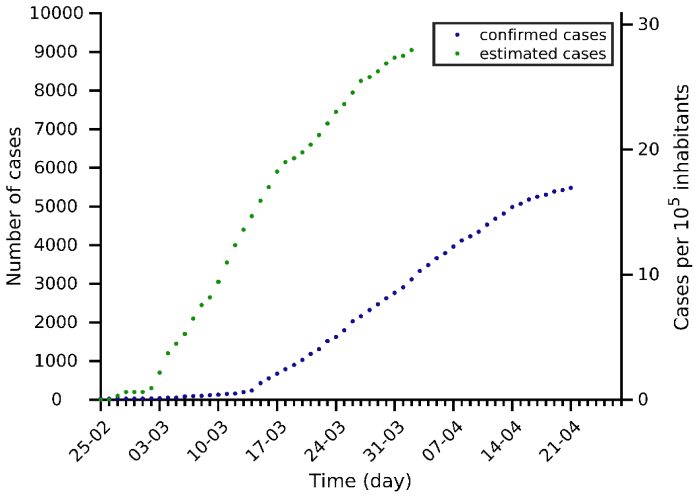


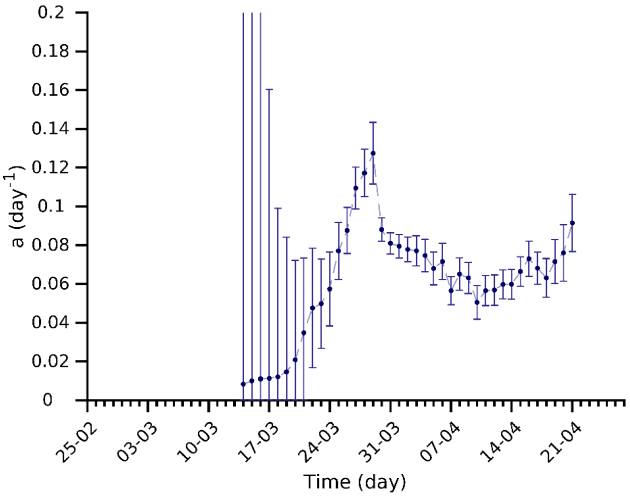


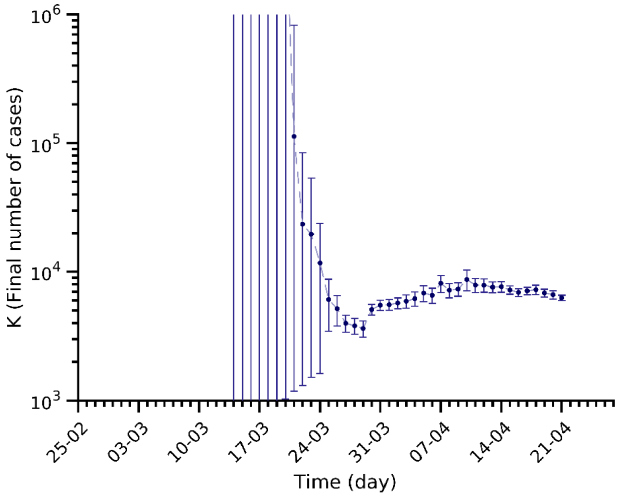


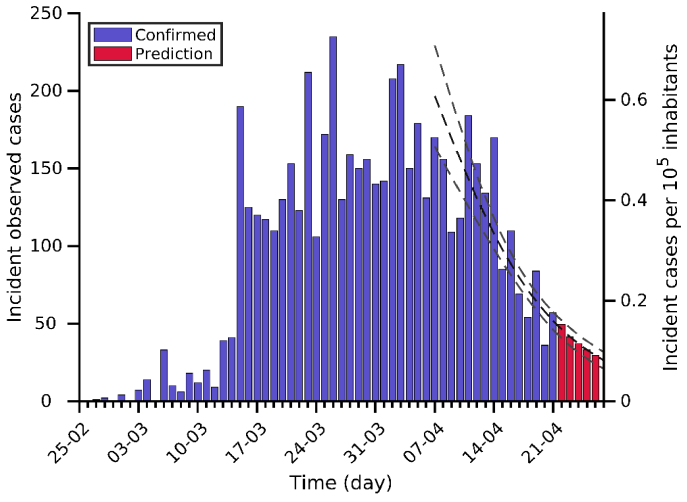
Malaysia 21-04-2020. Population: 32.4M. Current cumulated incidence: 17/10^5

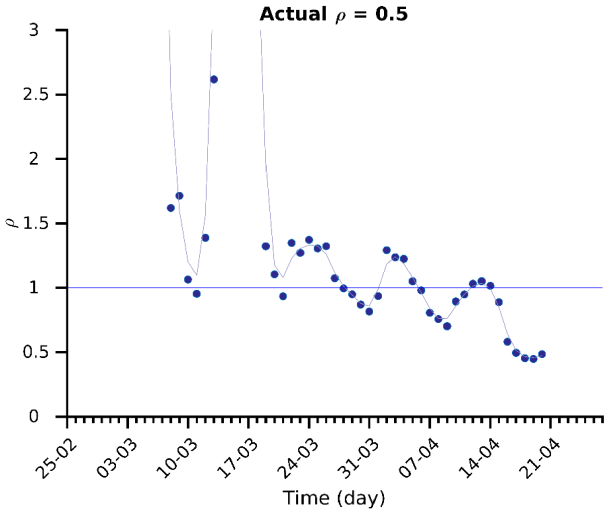


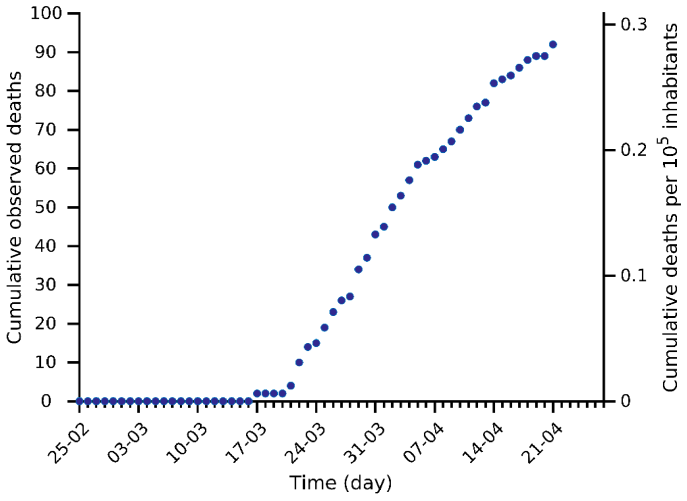


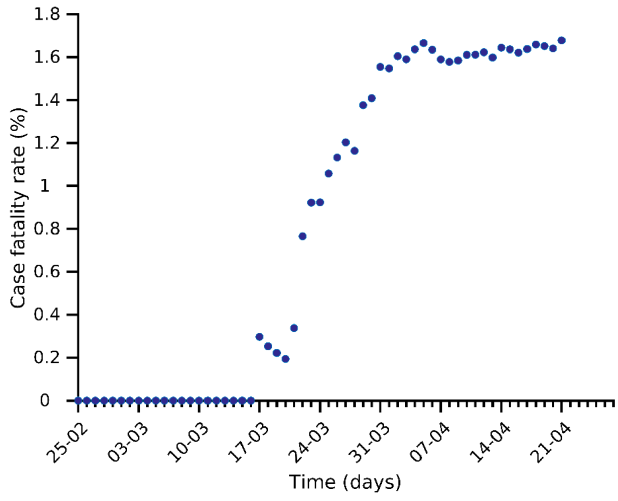




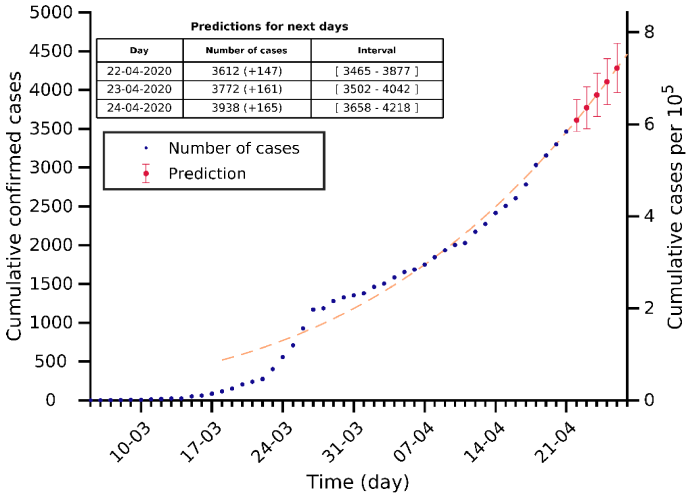


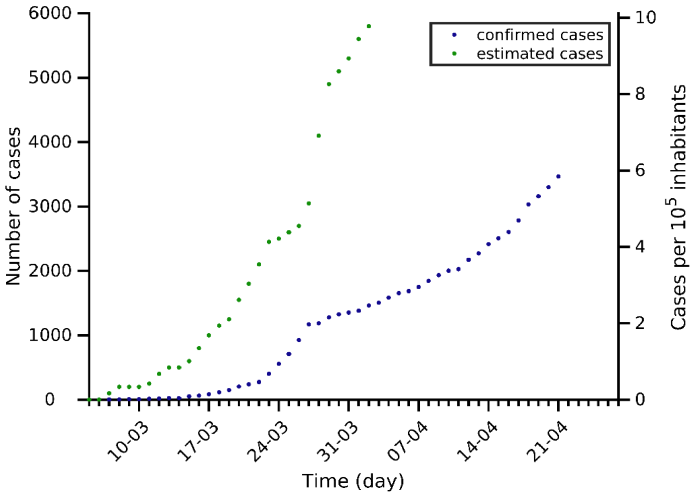


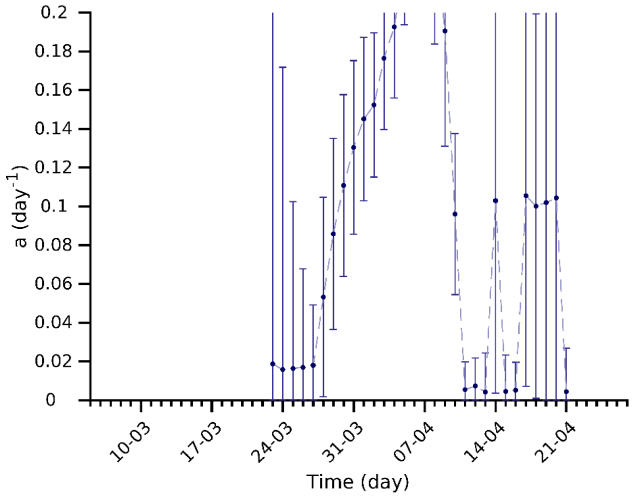


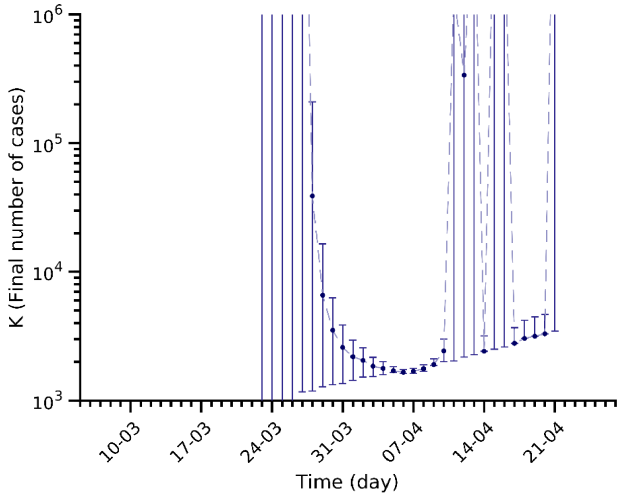


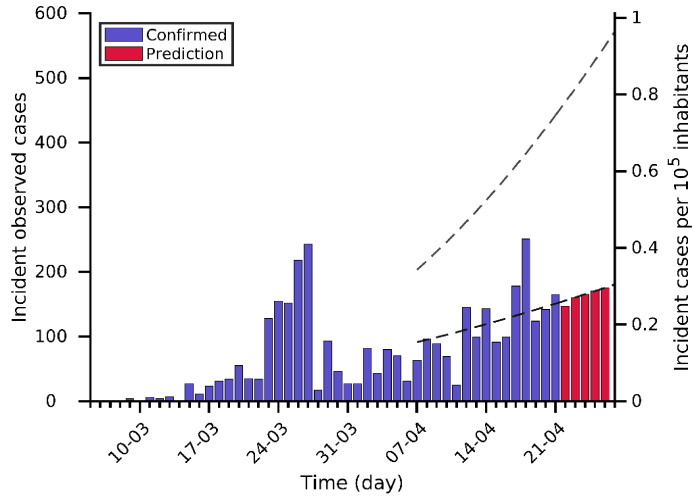
South Africa 21-04-2020. Population: 59.3M. Current cumulated incidence: $6/10^5$

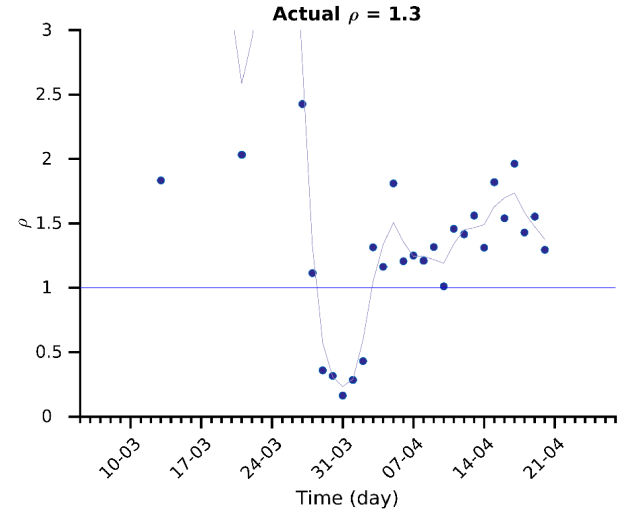


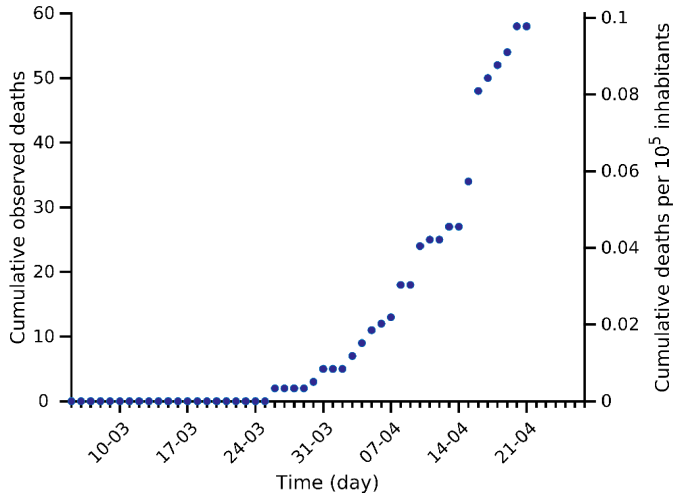


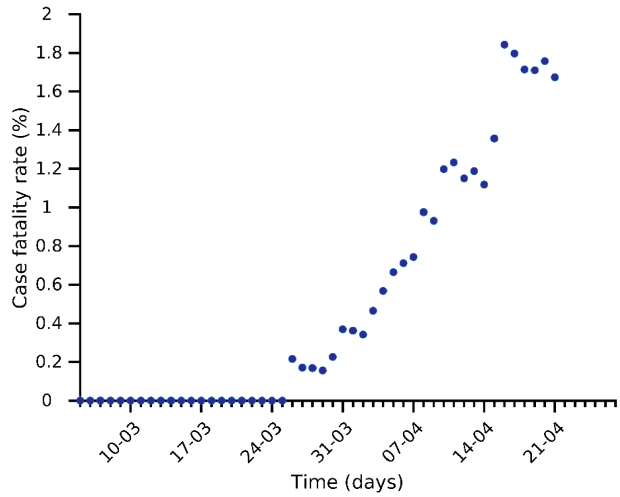








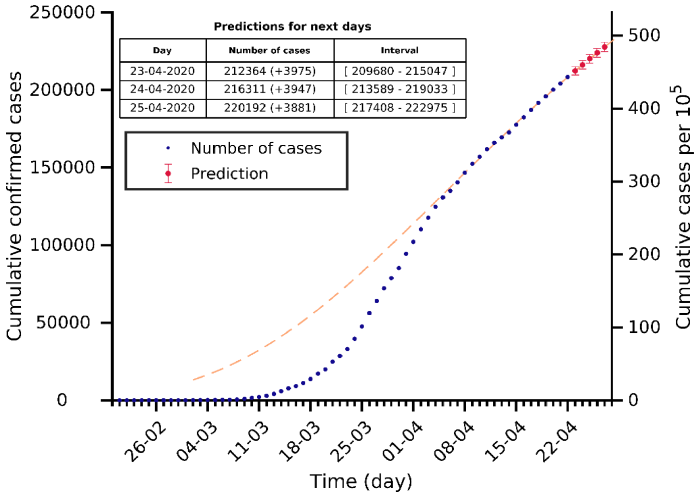


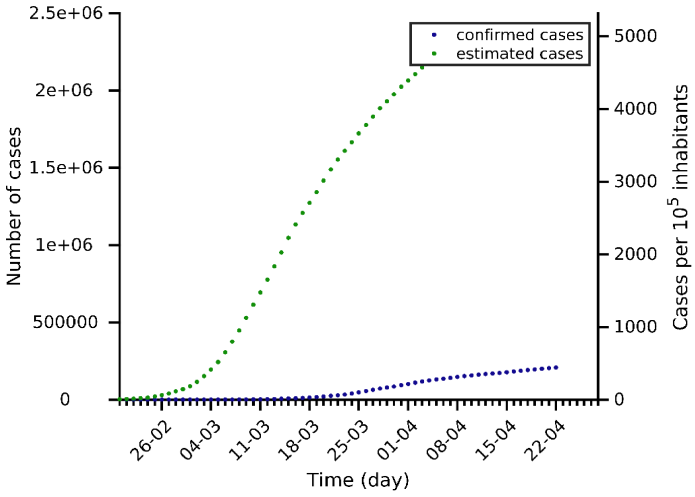


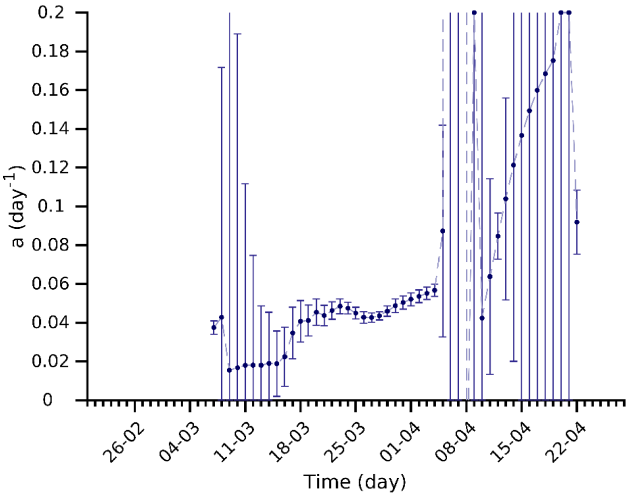
(3) Analysis and prediction of COVID-19 for Spain and its autonomous communities

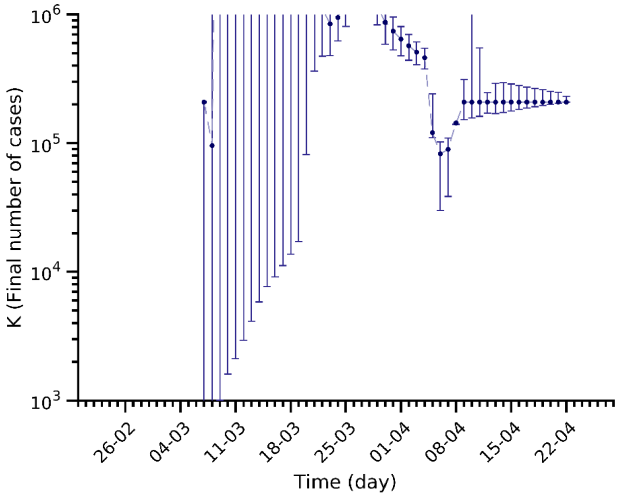
Data obtained from https://github.com/datadista/datasets/tree/master/COVID%2019 and https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm

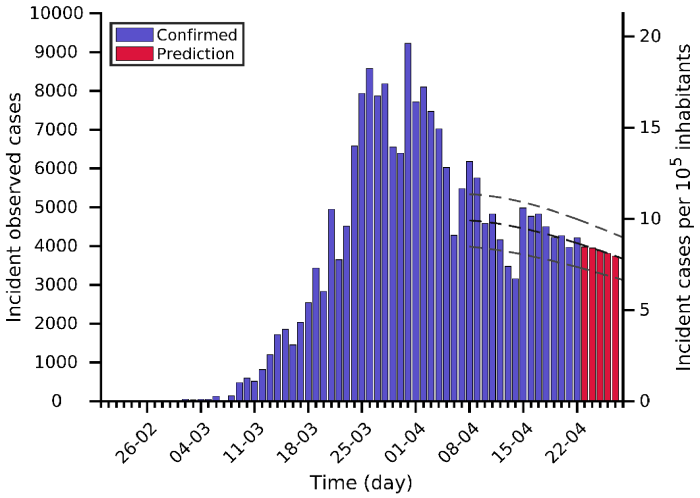
Spain 22-04-2020. Population: 47.0M. Current cumulated incidence: 443/10⁵

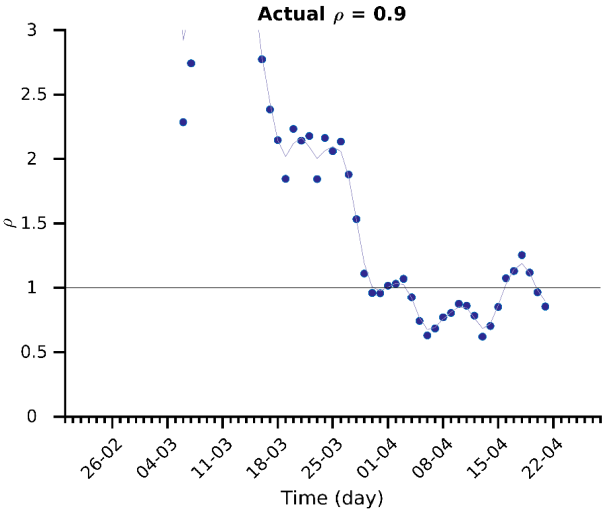


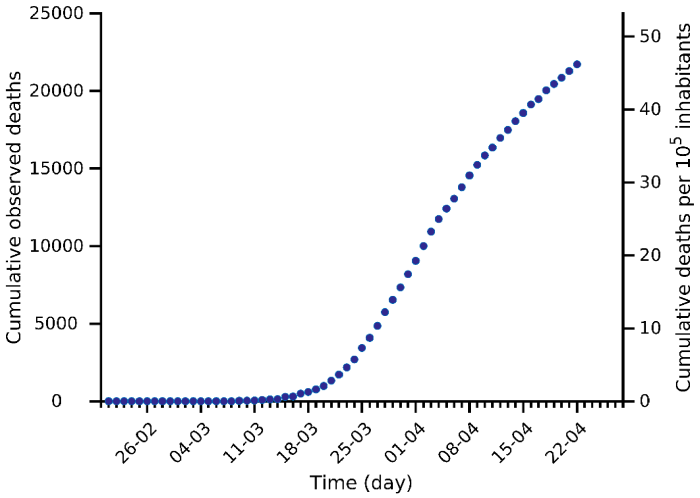


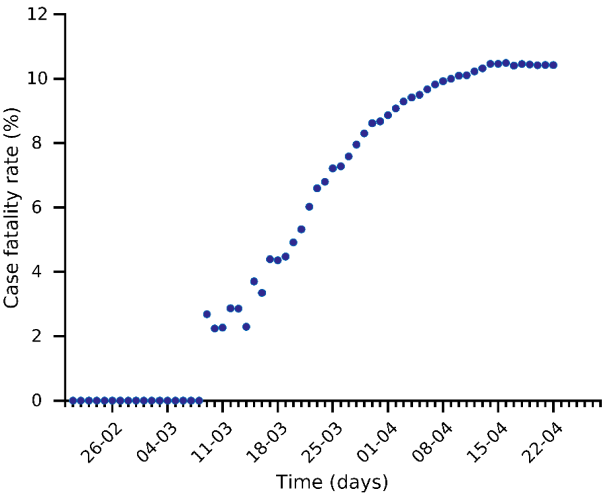




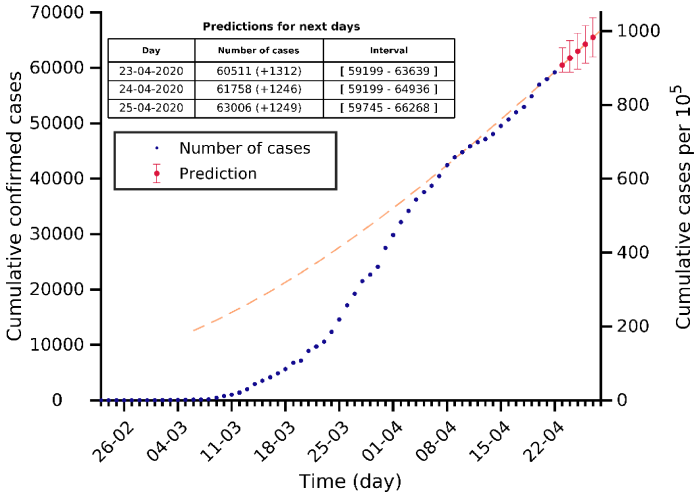


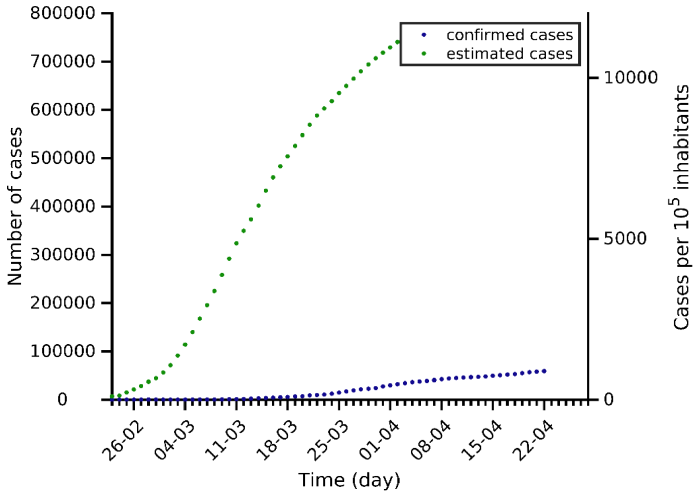


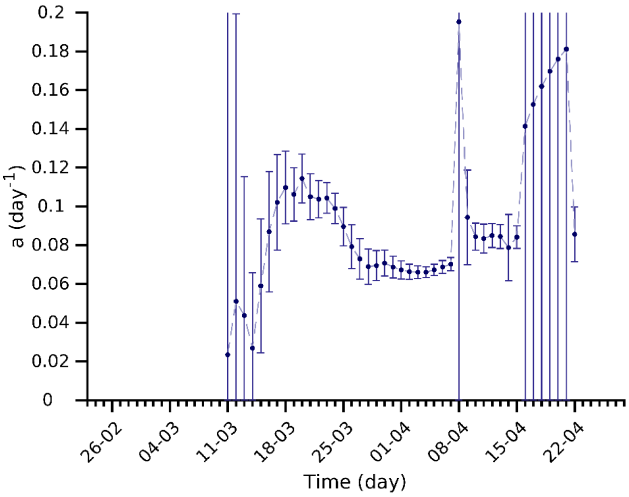


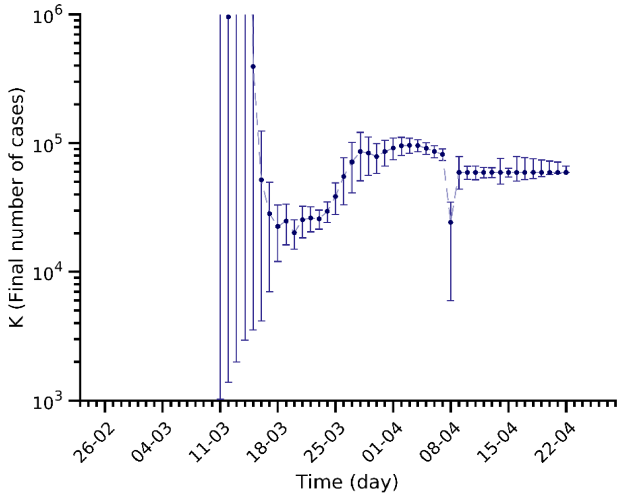


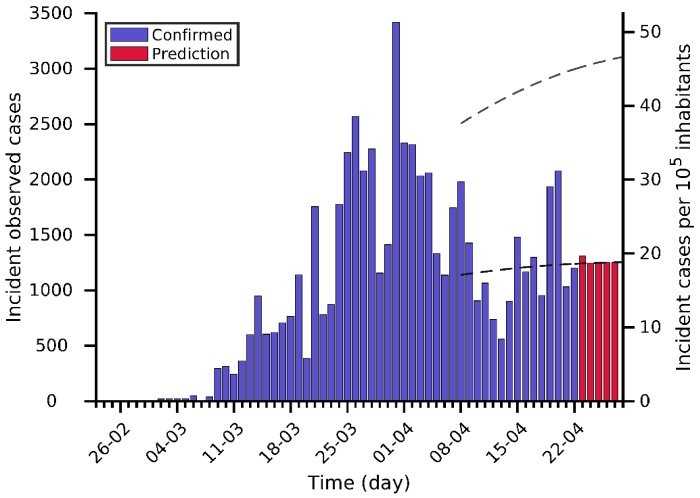
Madrid 22-04-2020. Population: 6.7M. Current cumulated incidence: 888/10^5

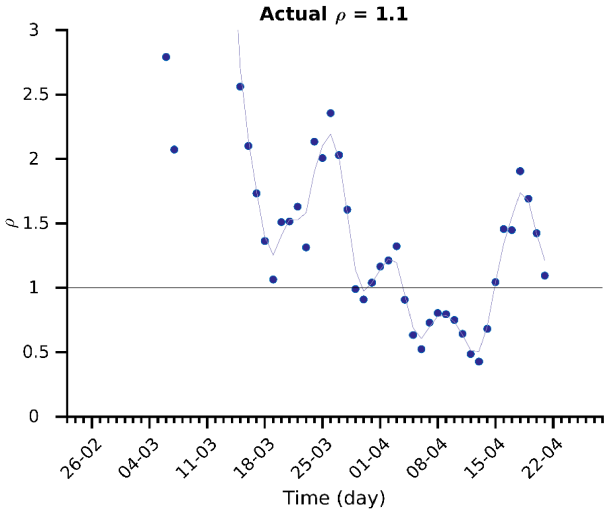


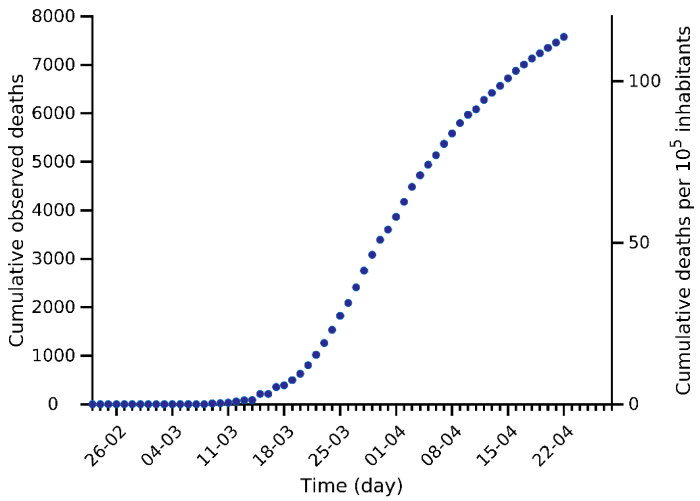


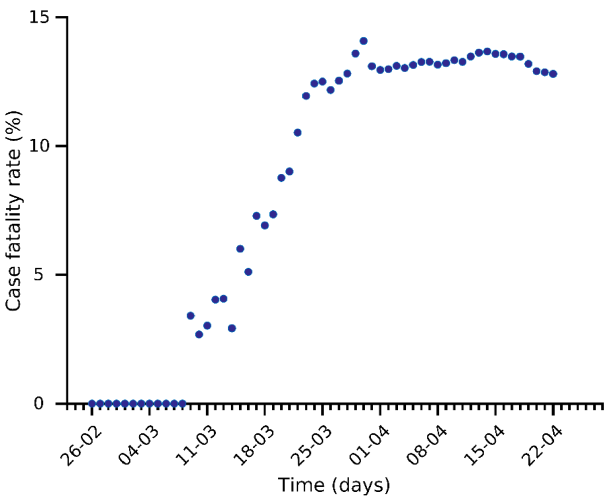




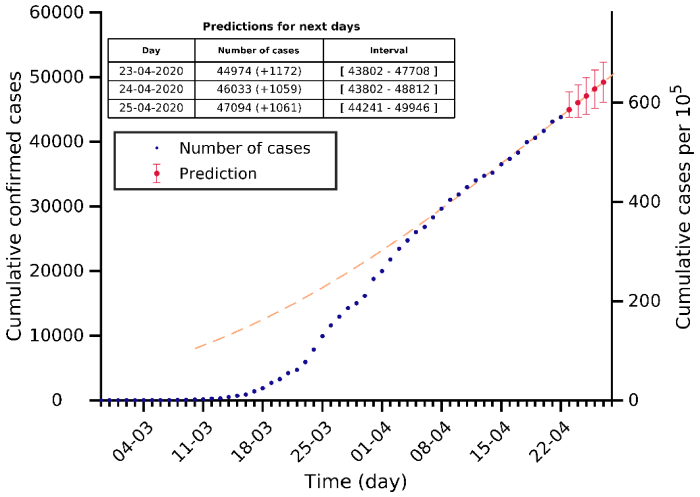


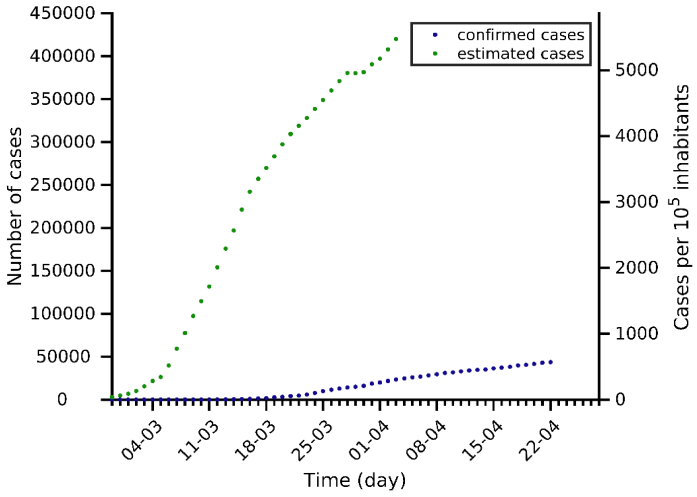


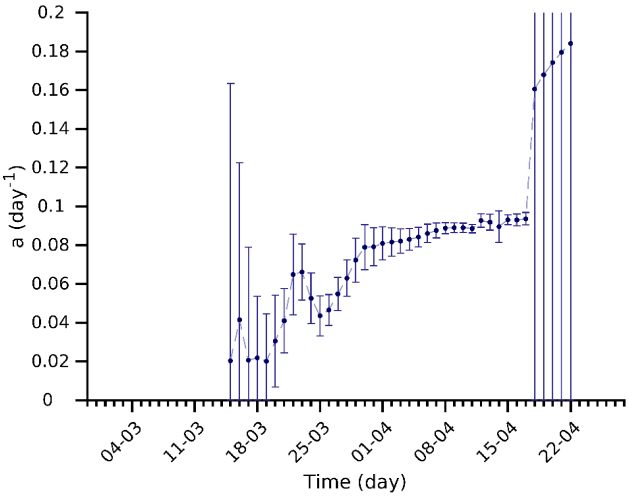


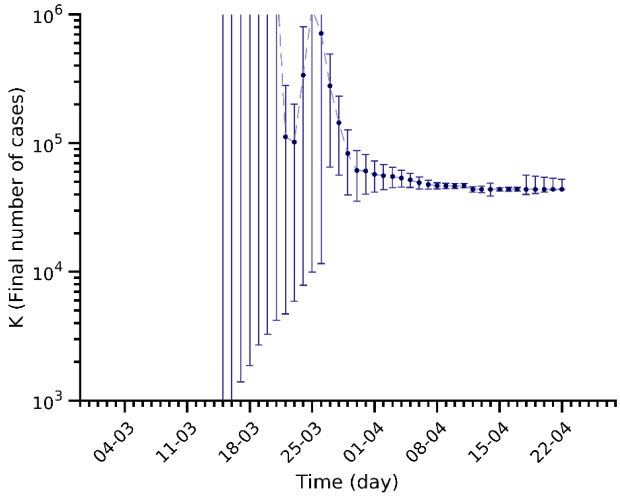


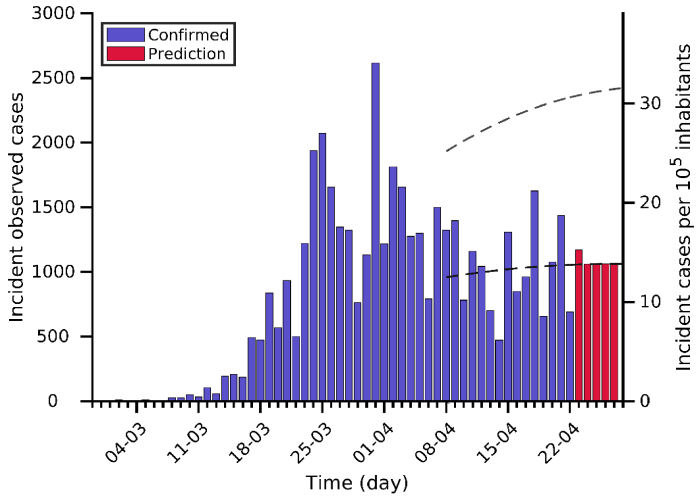
Catalunya 22-04-2020. Population: 7.7M. Current cumulated incidence: 571/10^5

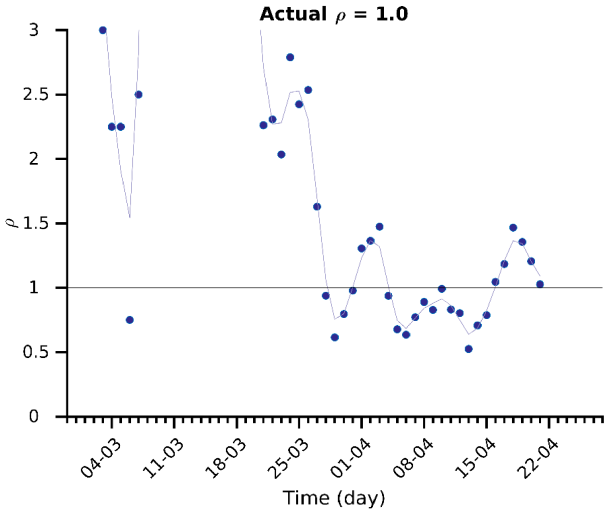


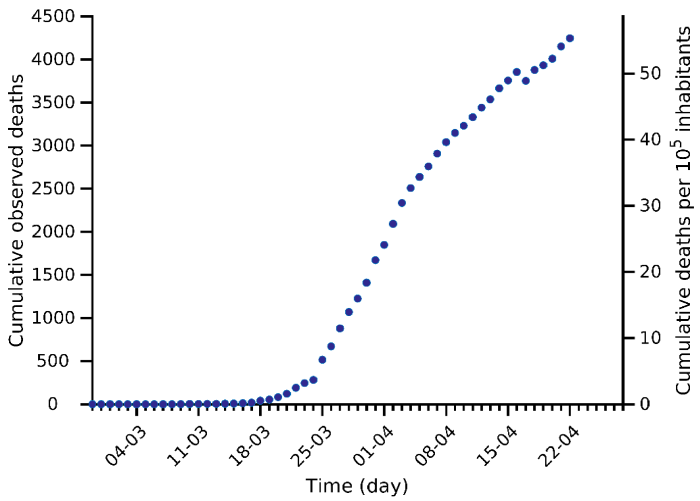


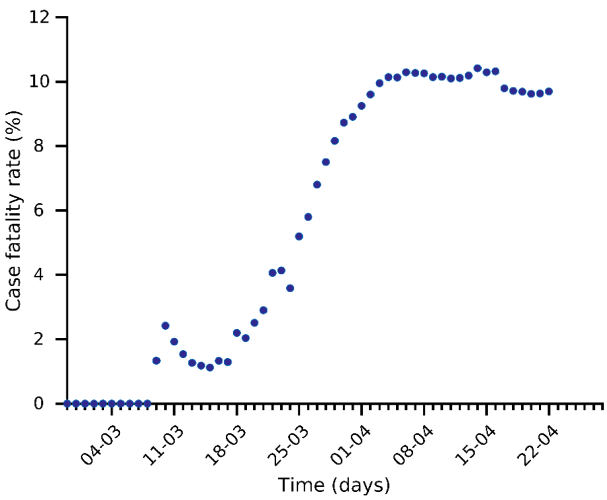




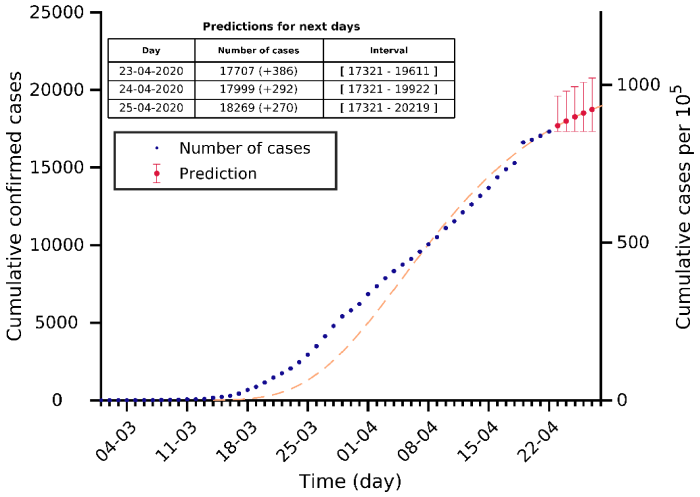


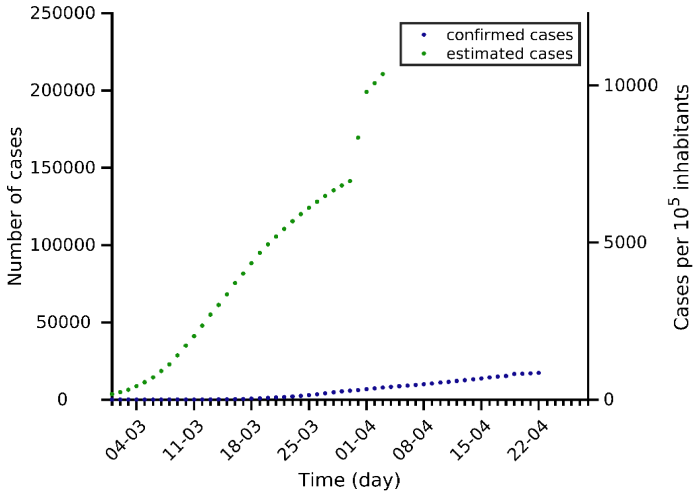


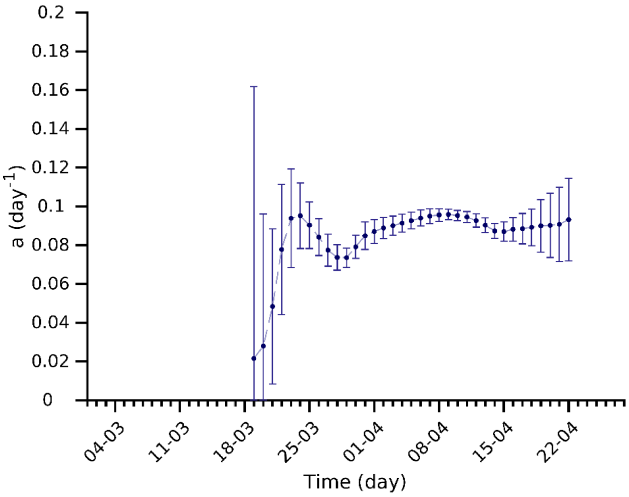


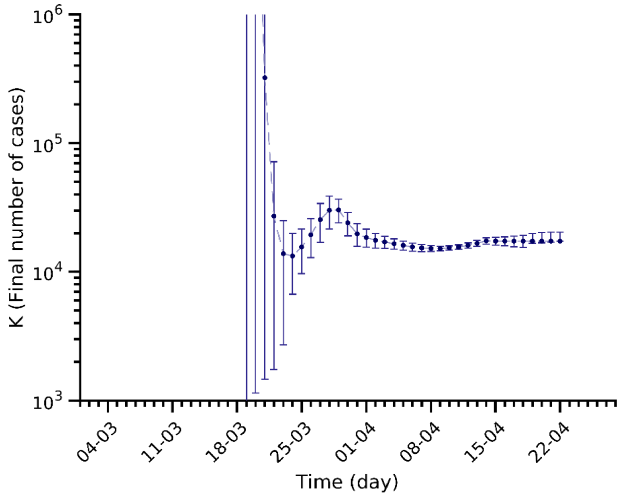


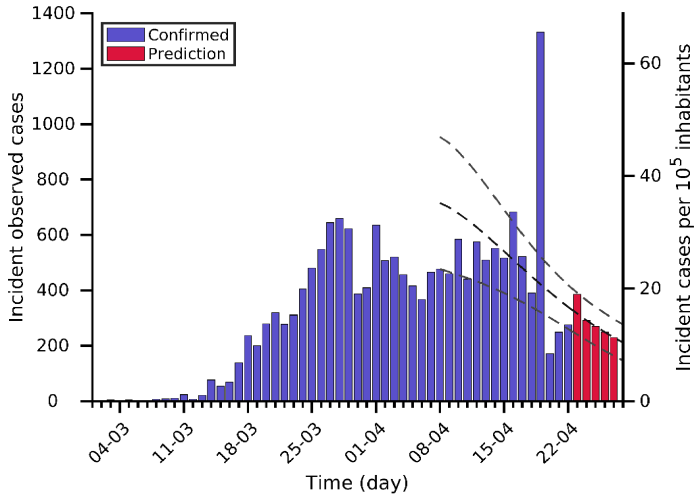
Castilla-La Mancha 22-04-2020. Population: 2.0M. Current cumulated incidence: 85

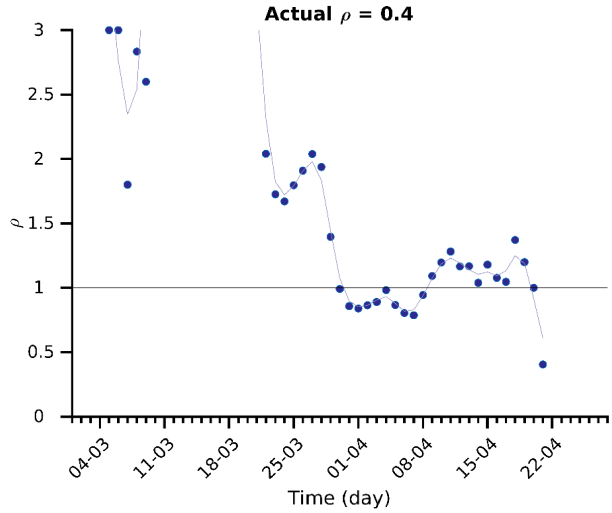


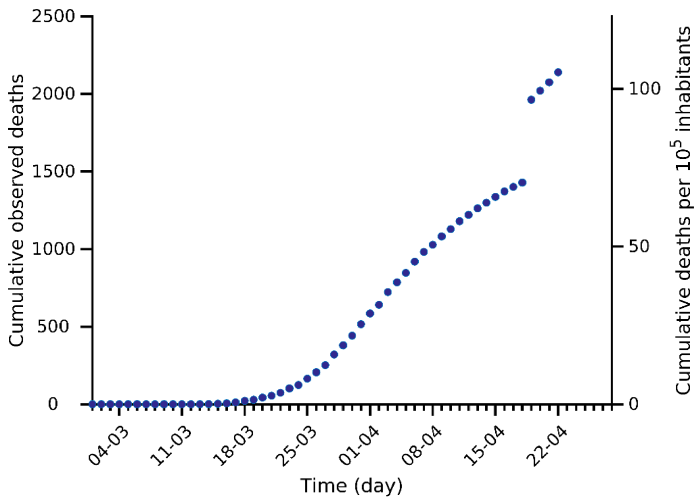


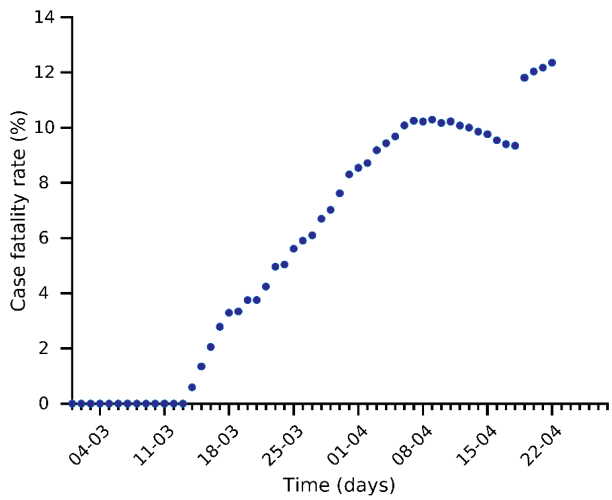




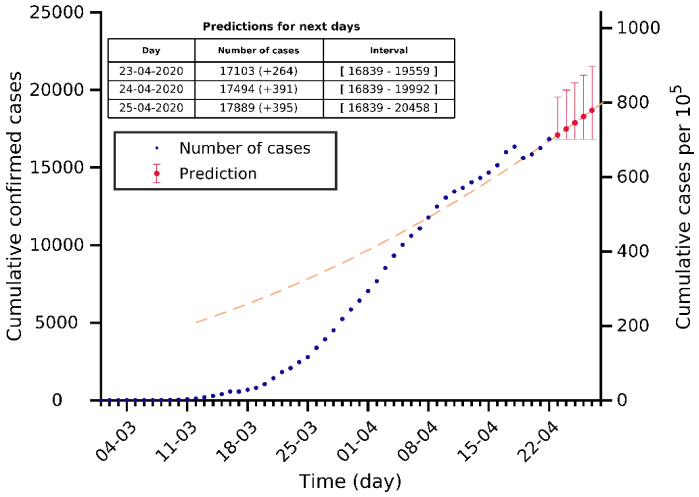


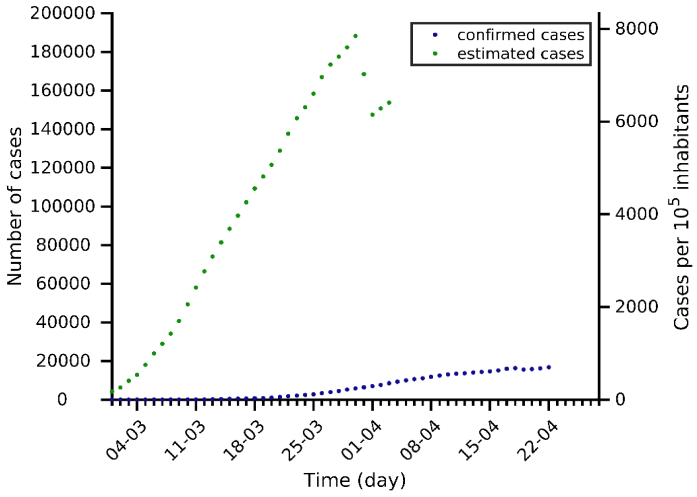


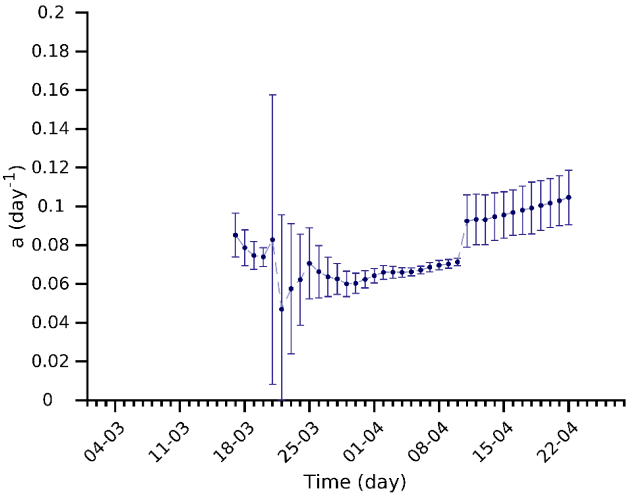


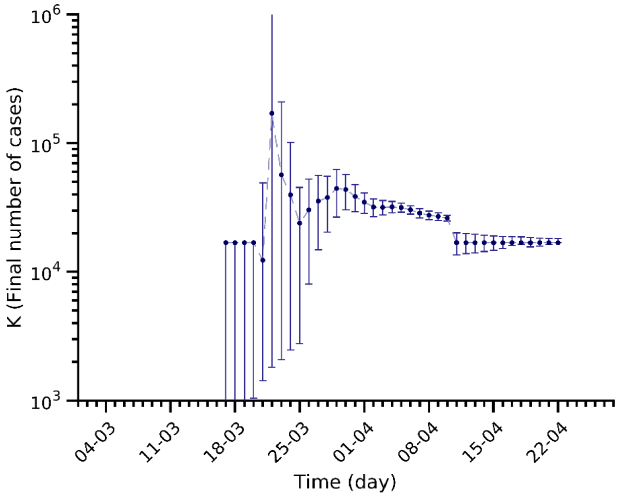


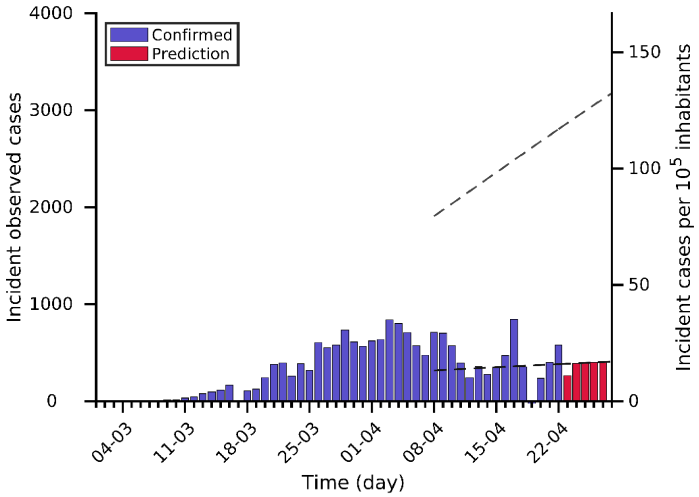
Castilla Leon 22-04-2020. Population: 2.4M. Current cumulated incidence: 702/10^5

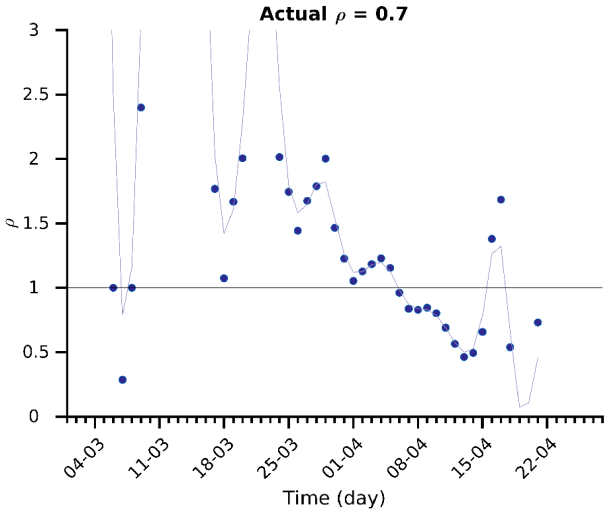


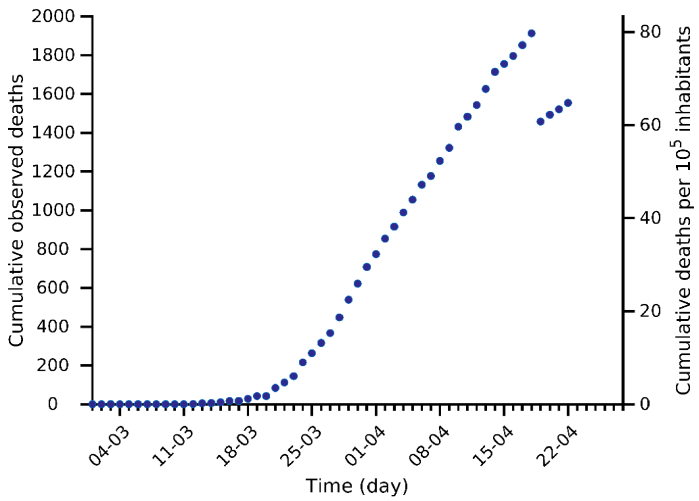


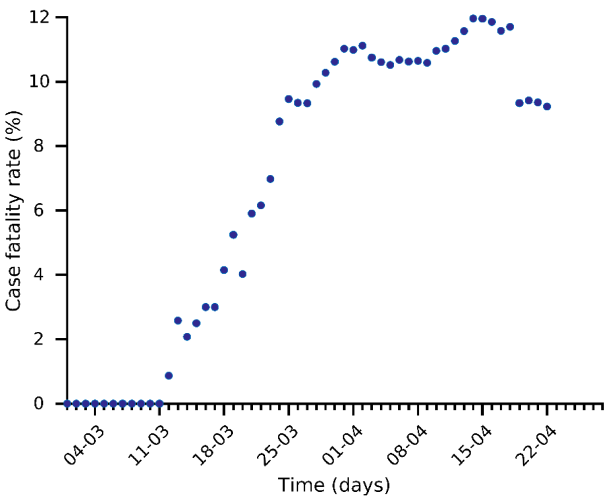




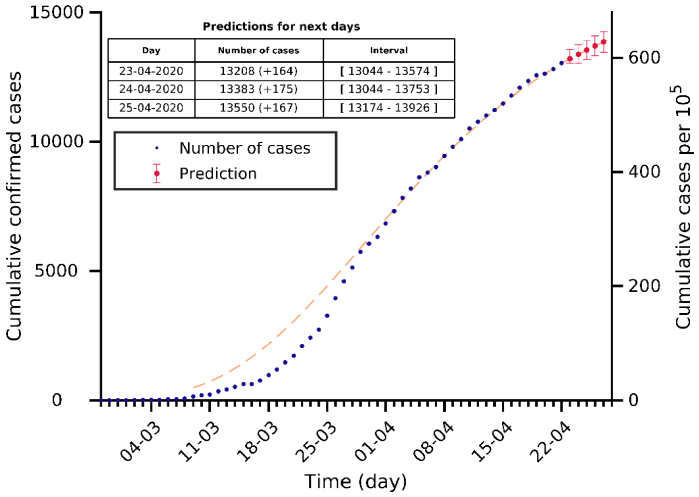


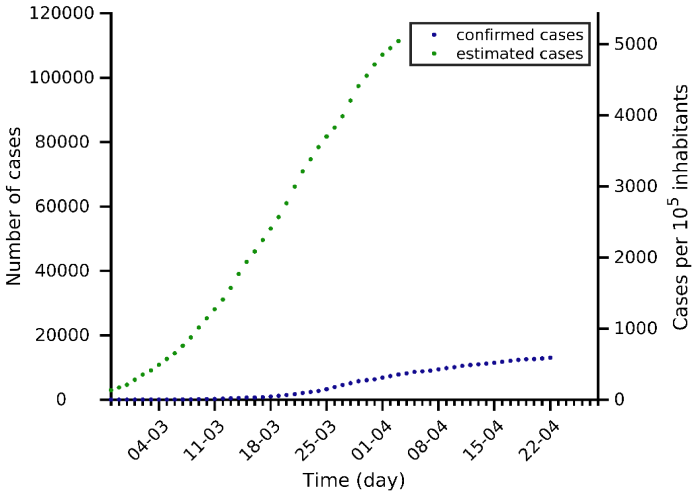


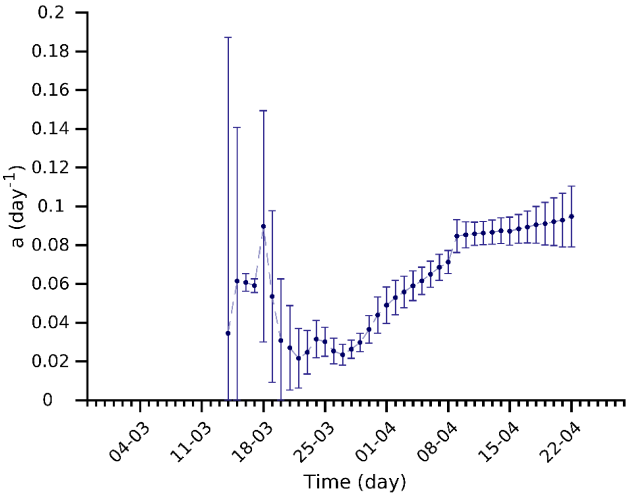


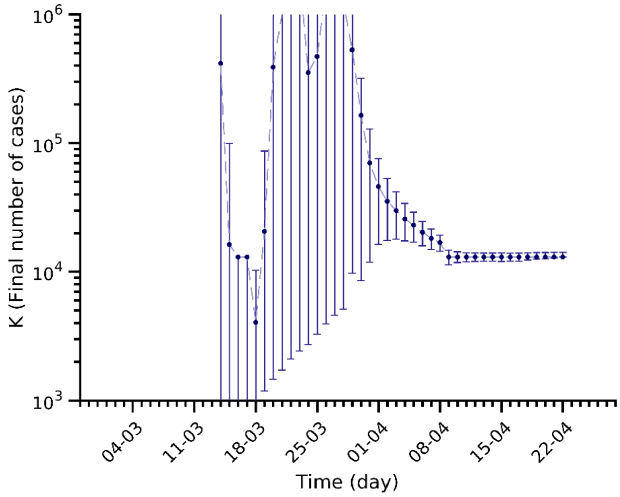


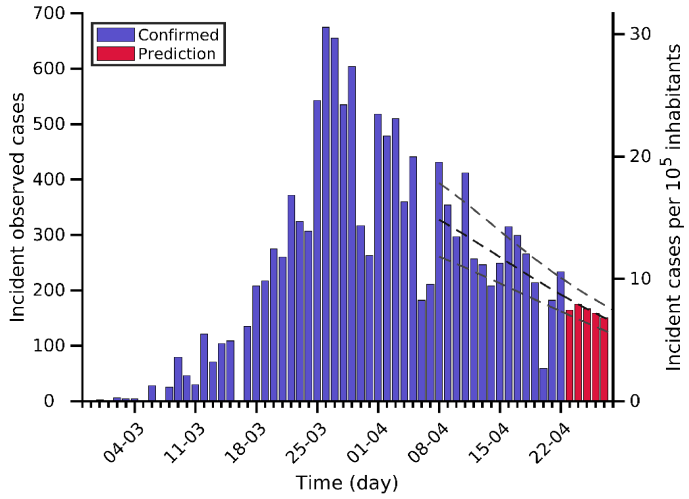
Euskadi 22-04-2020. Population: 2.2M. Current cumulated incidence: 591/10^5

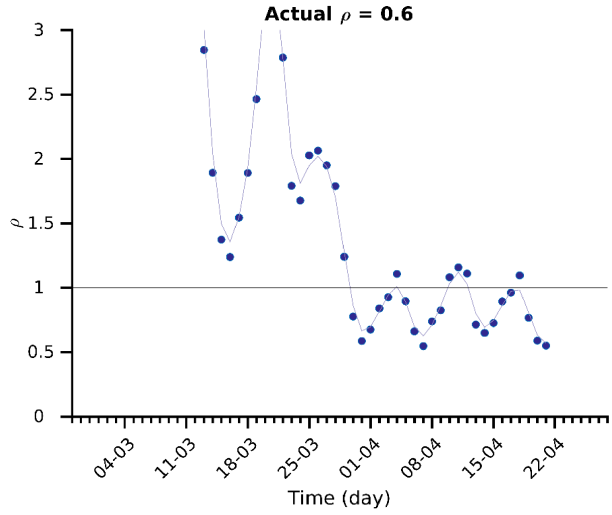


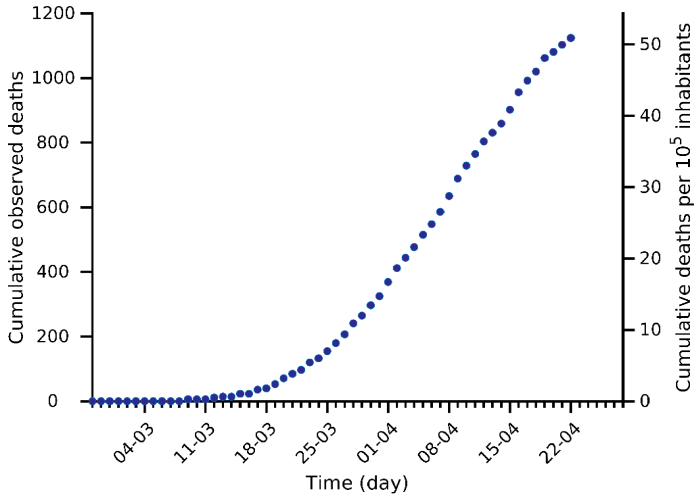


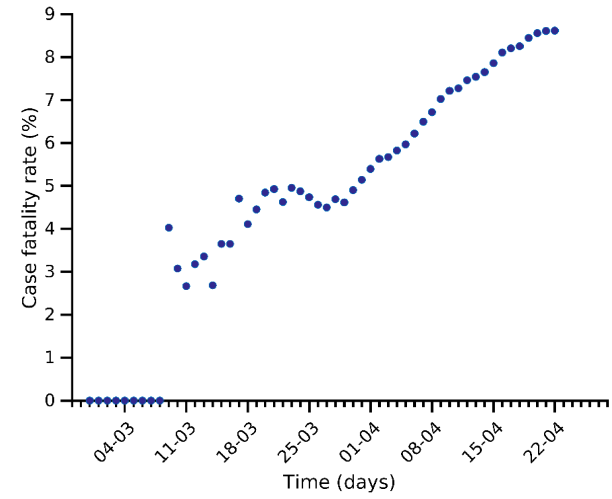




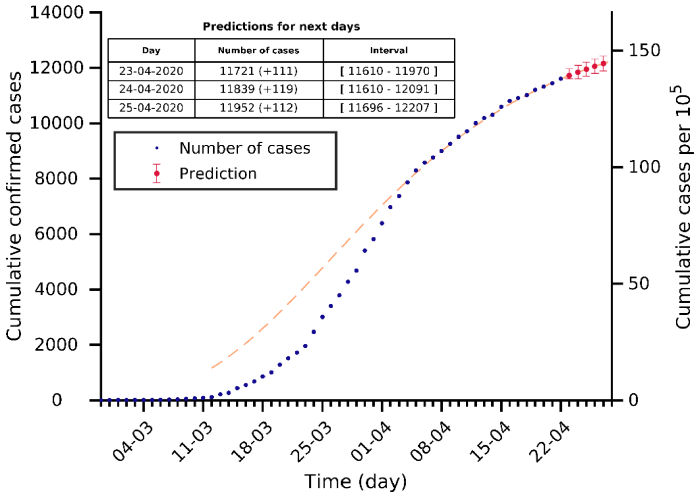


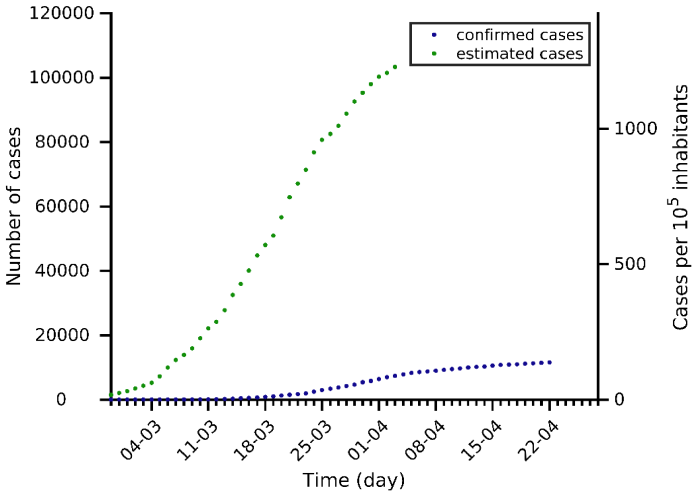


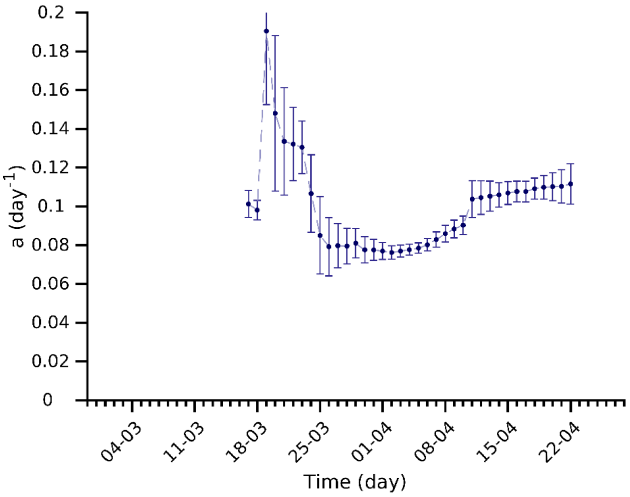


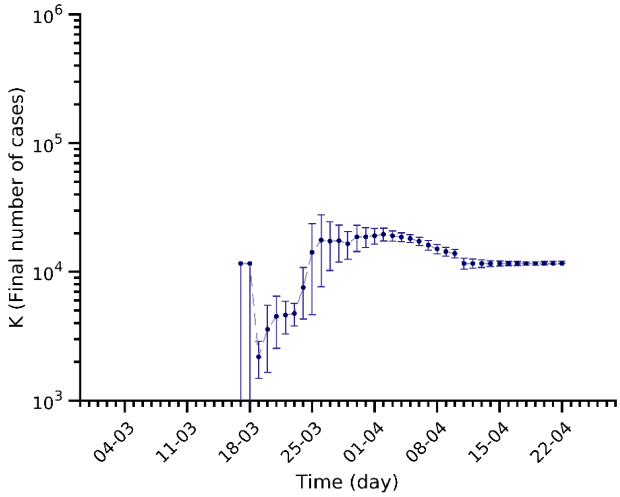


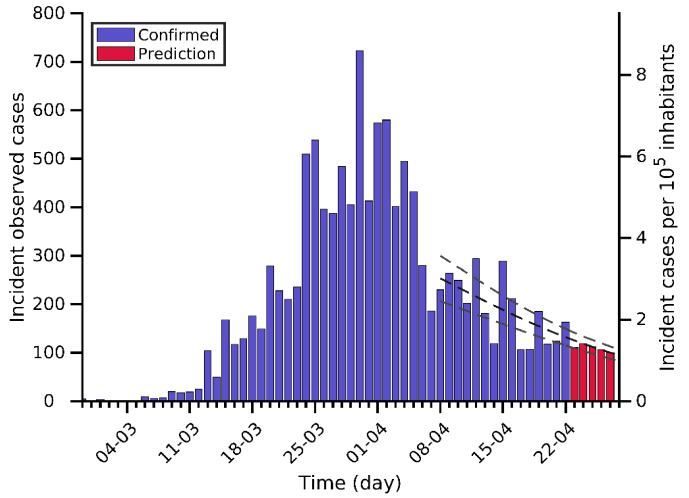
Andalucia 22-04-2020. Population: 8.4M. Current cumulated incidence: 138/10⁵

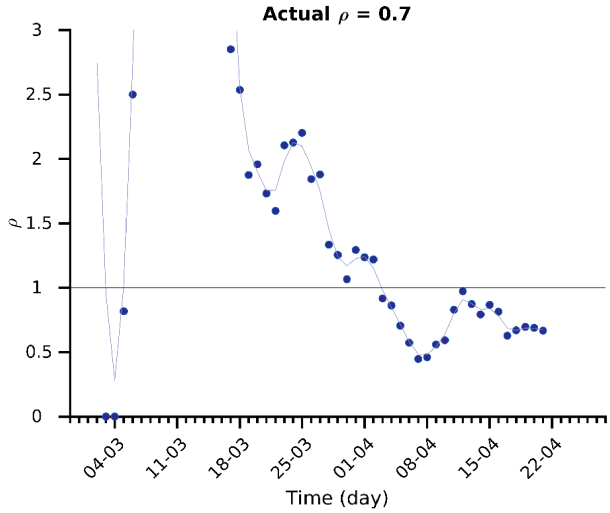


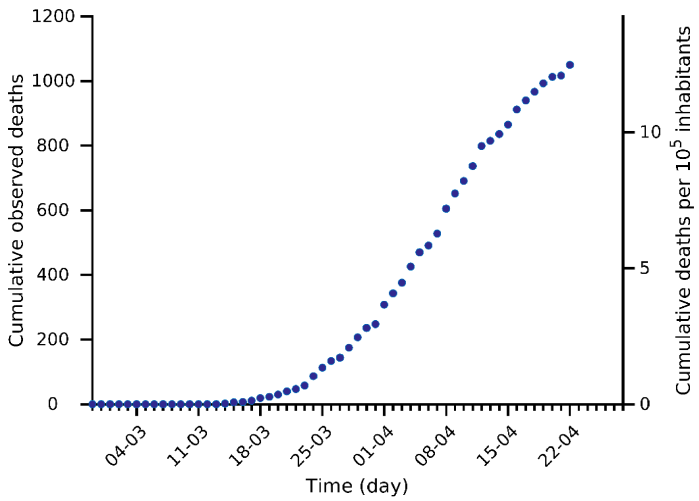


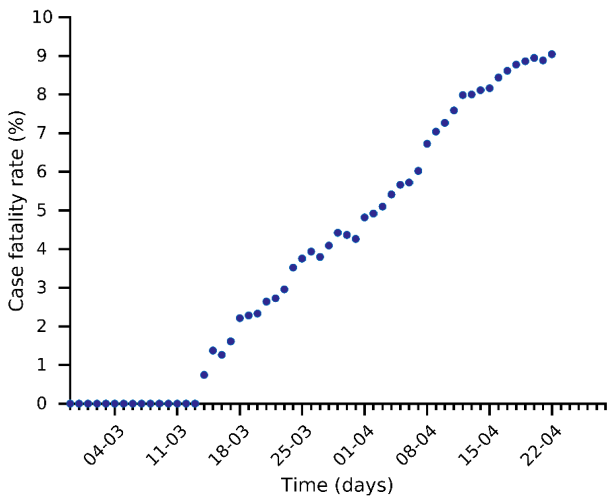




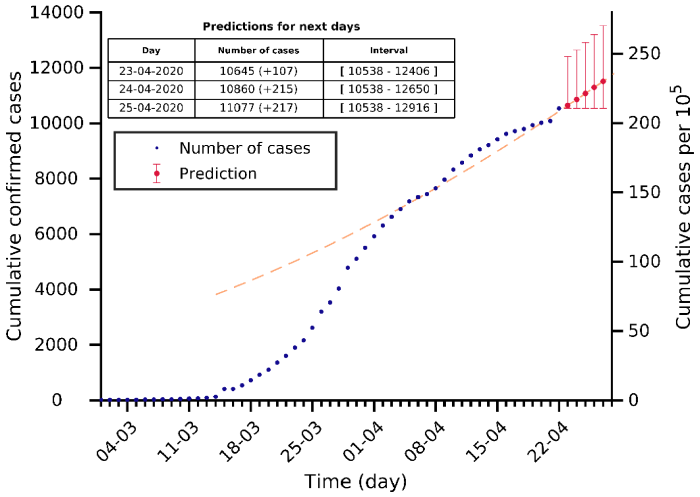


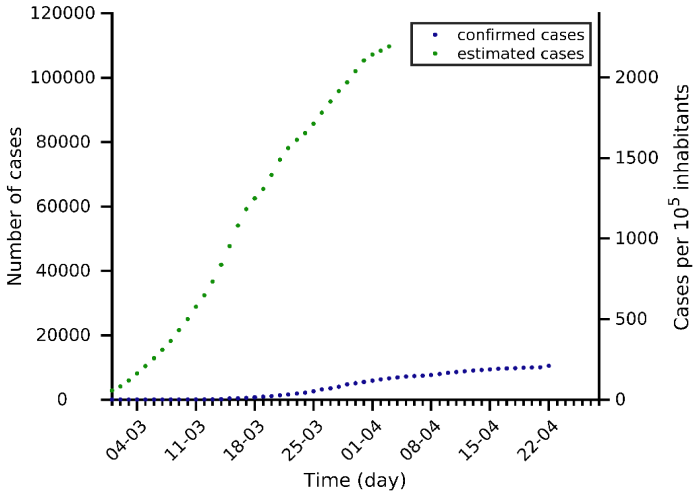


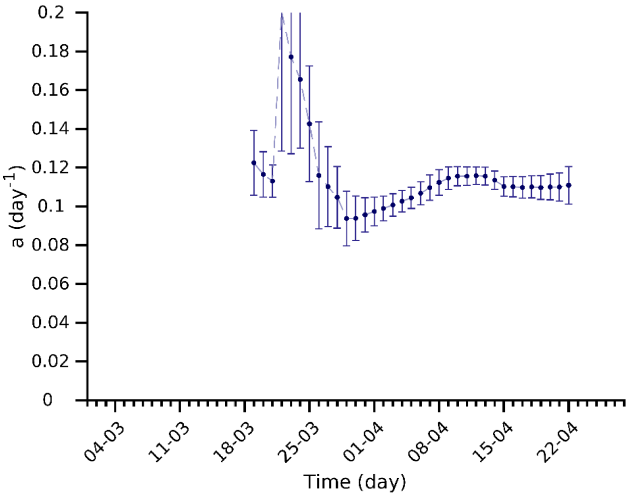


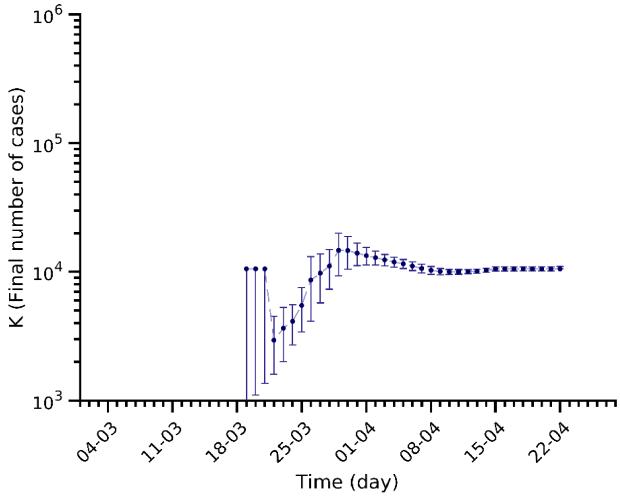


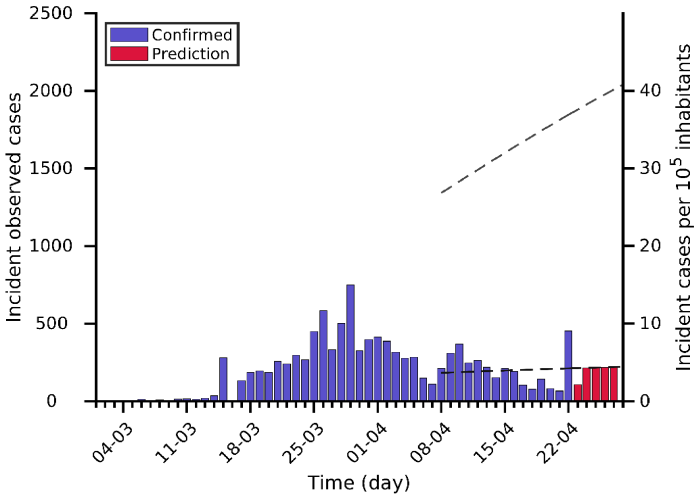
C Valenciana 22-04-2020. Population: 5.0M. Current cumulated incidence: 211/10^5

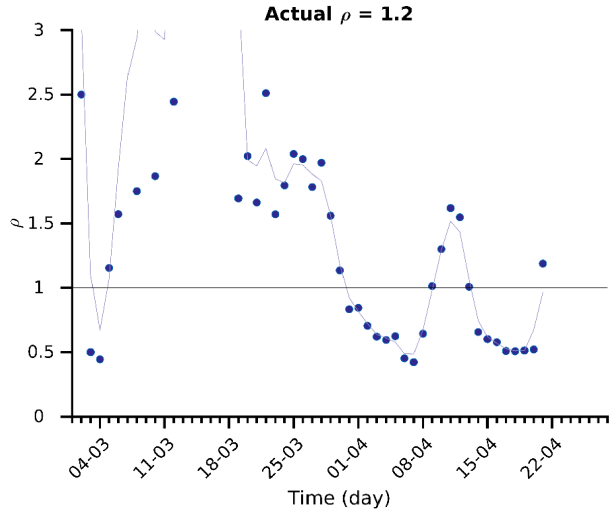


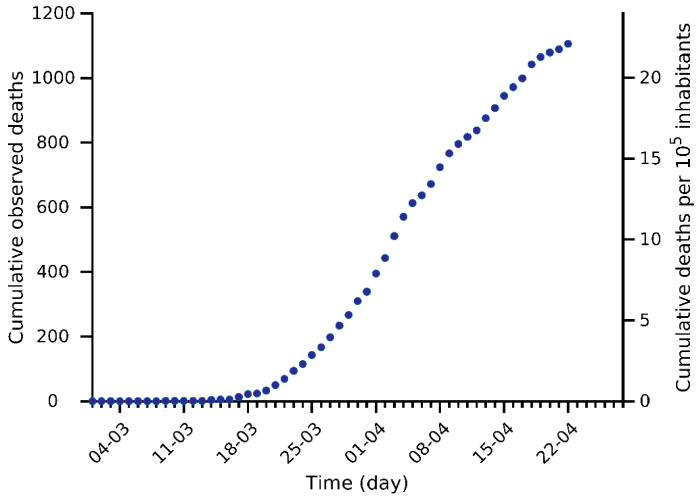


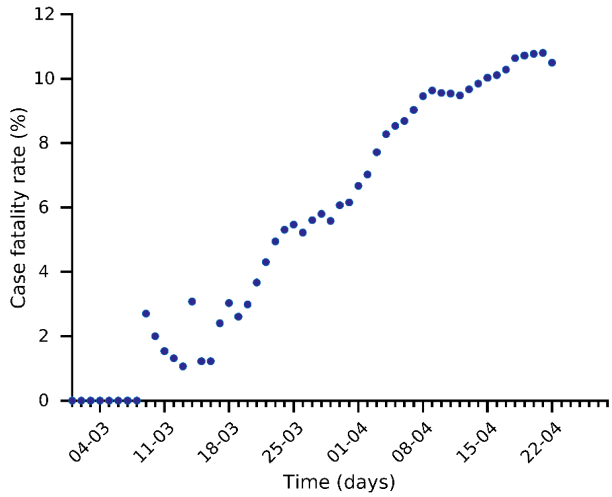




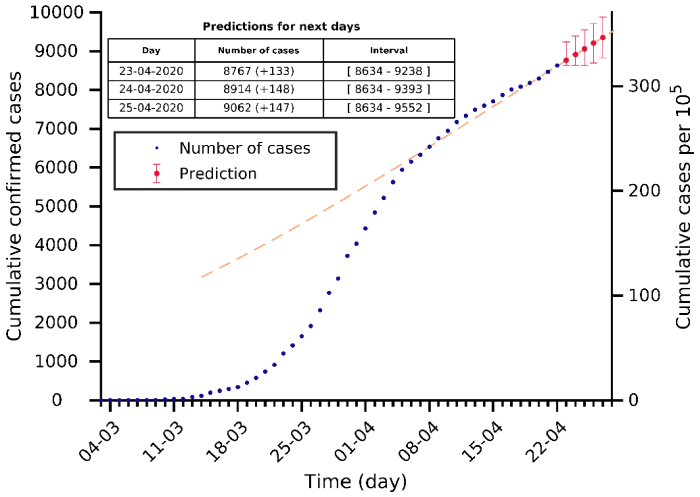


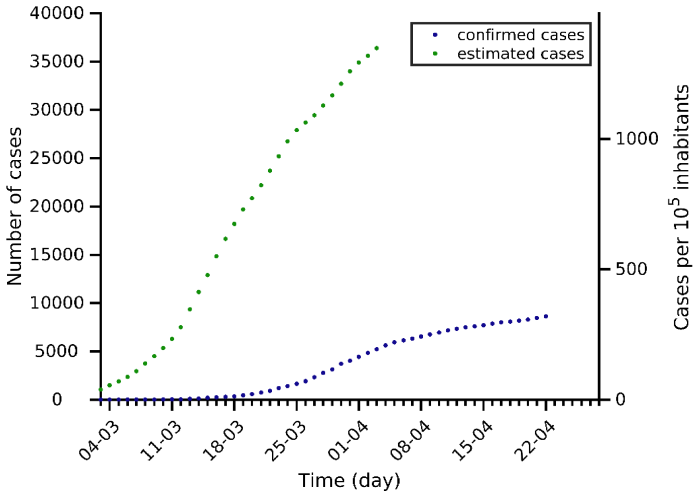


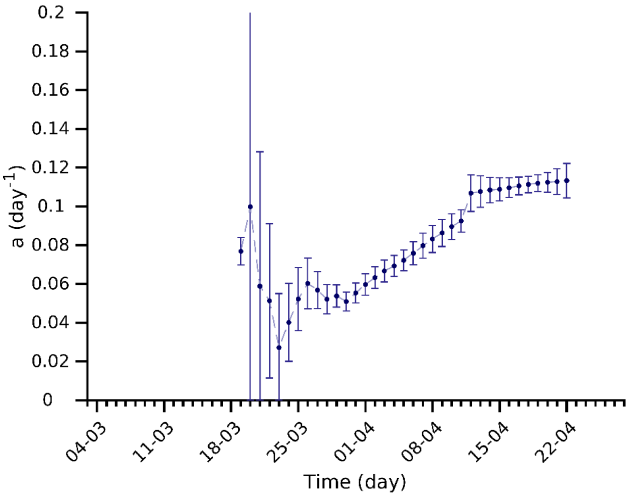


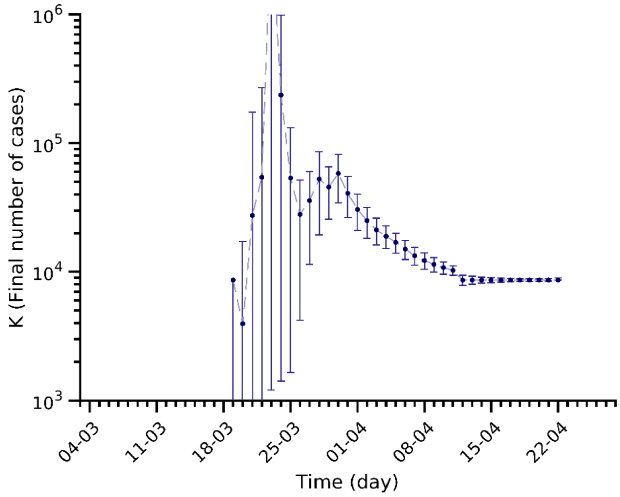


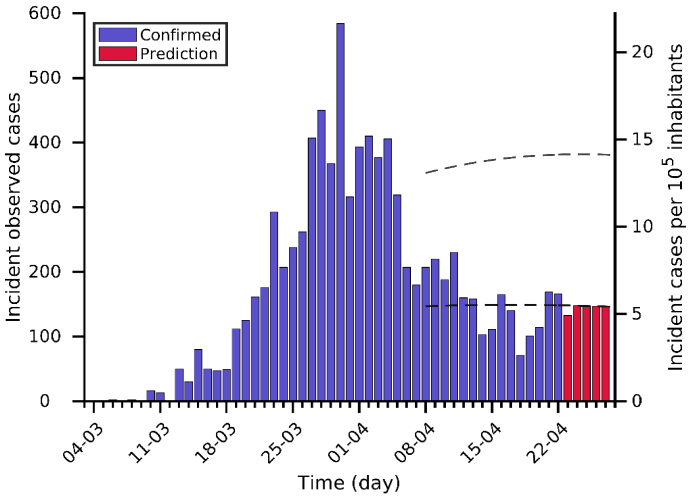
Galicia 22-04-2020. Population: 2.7M. Current cumulated incidence: 320/10⁵

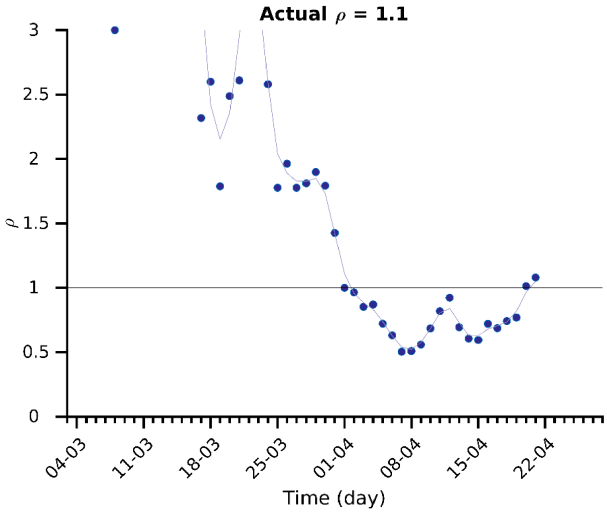


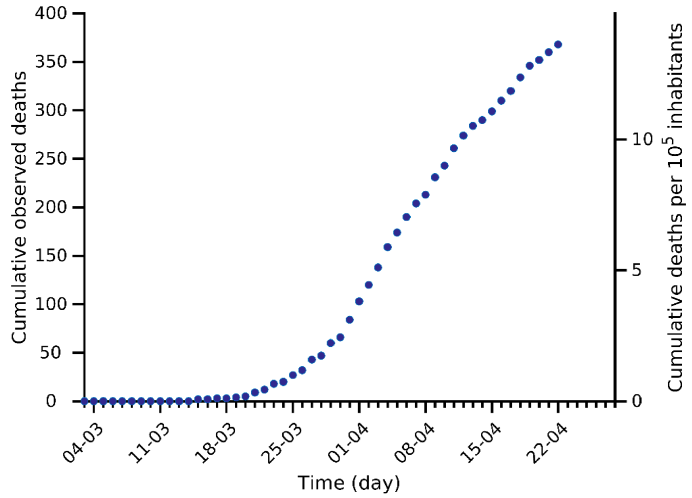


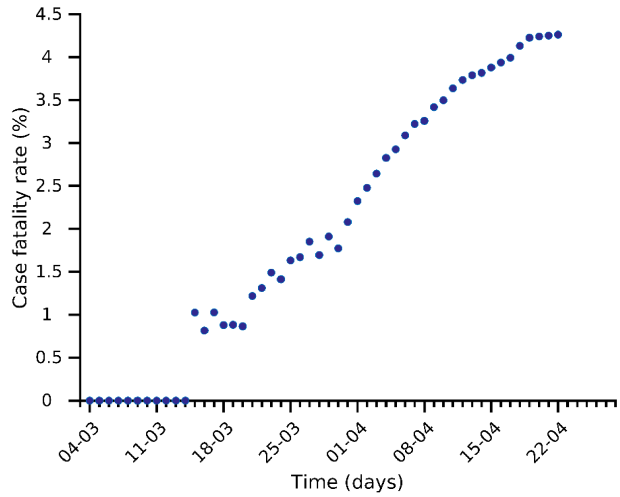




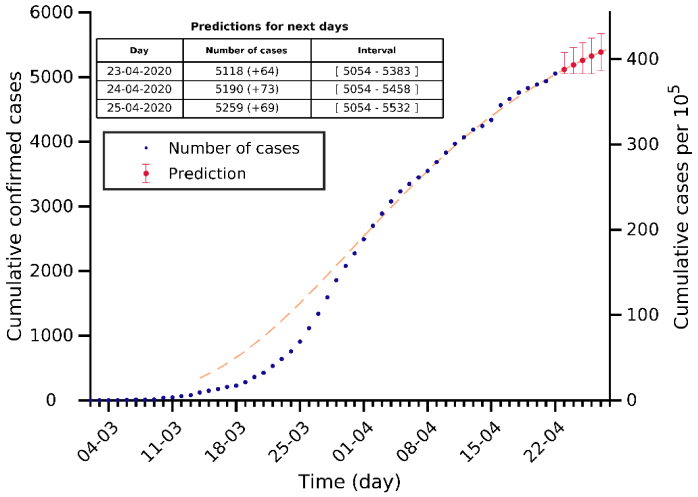


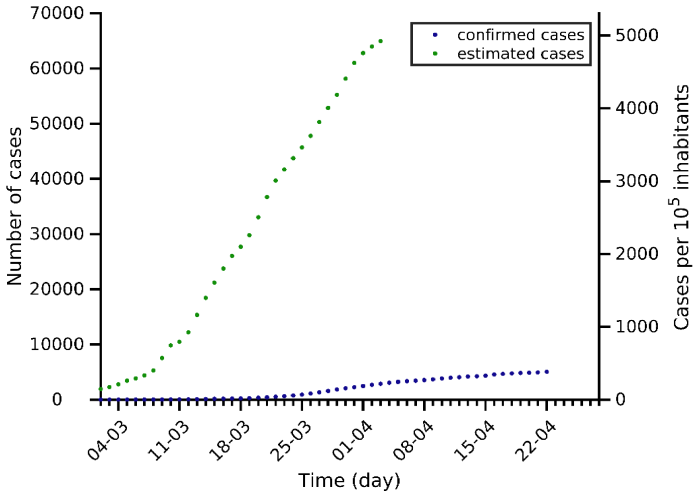


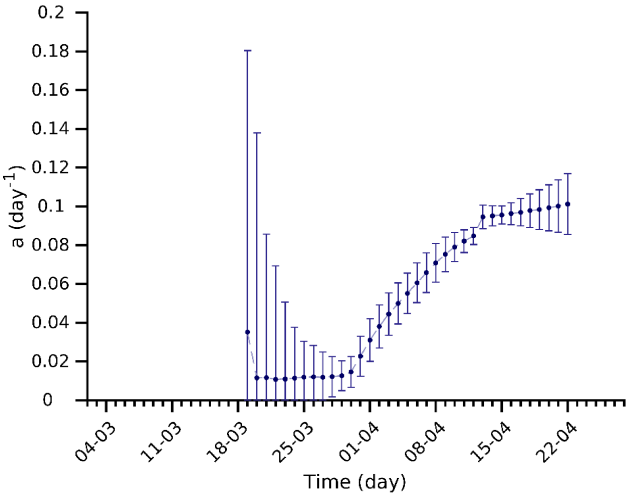


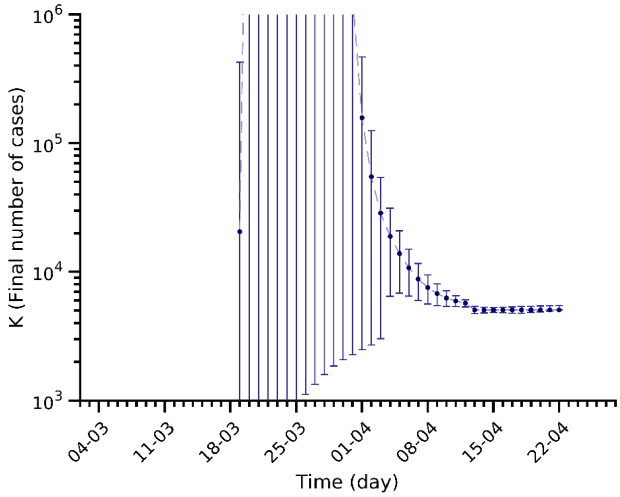


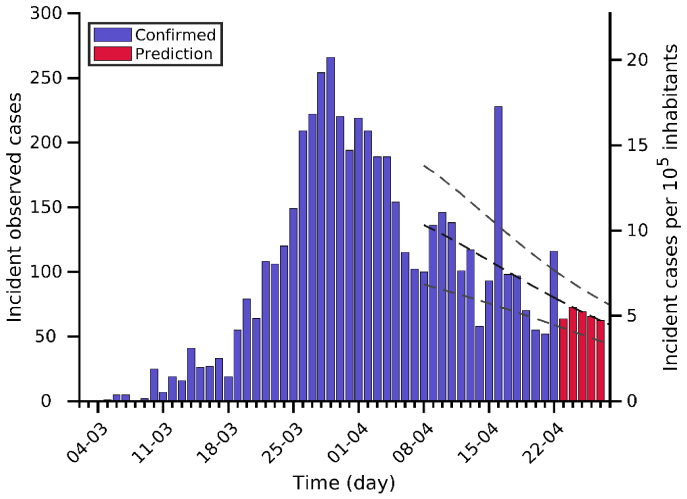
Aragon 22-04-2020. Population: 1.3M. Current cumulated incidence: $383/10^5$

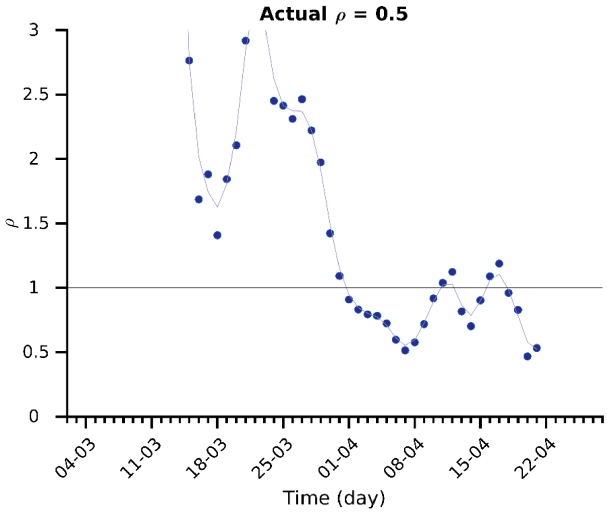


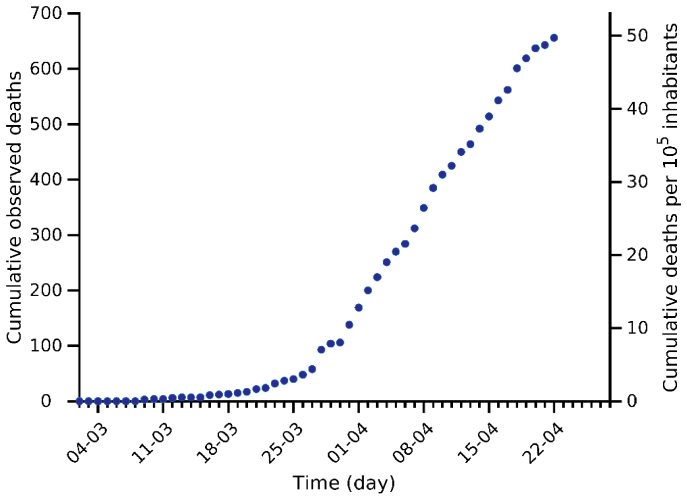


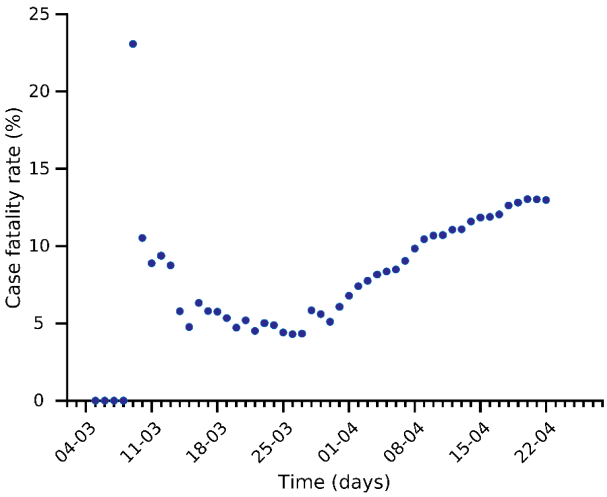




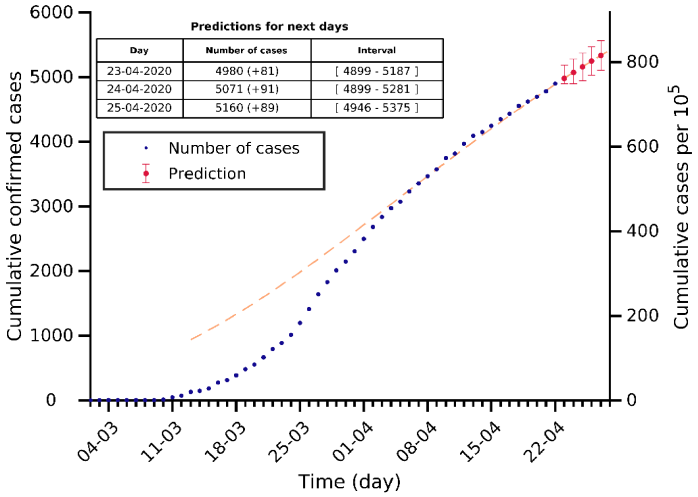


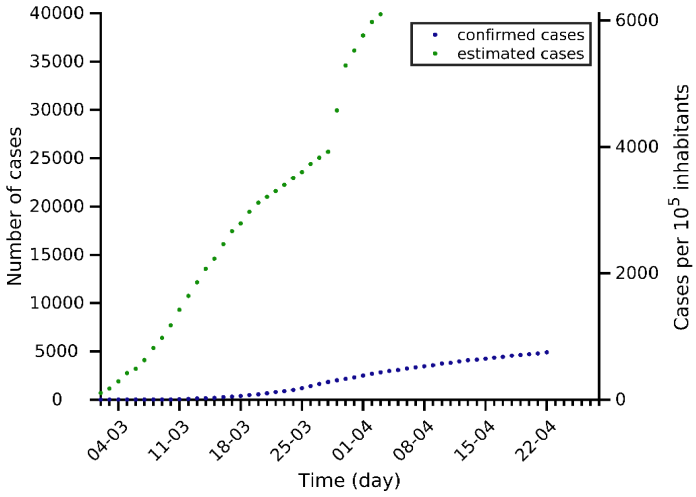


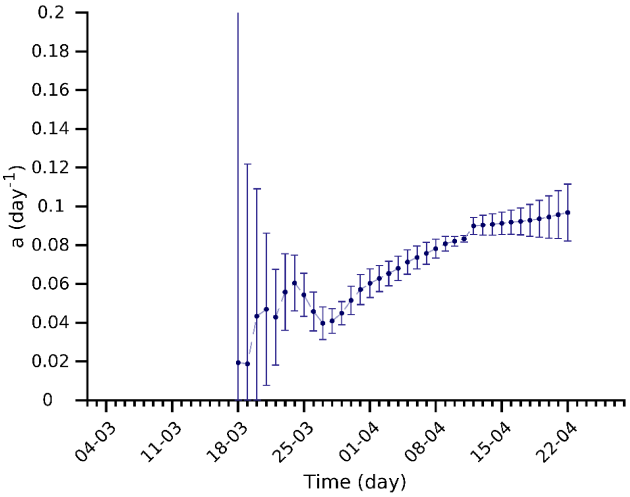


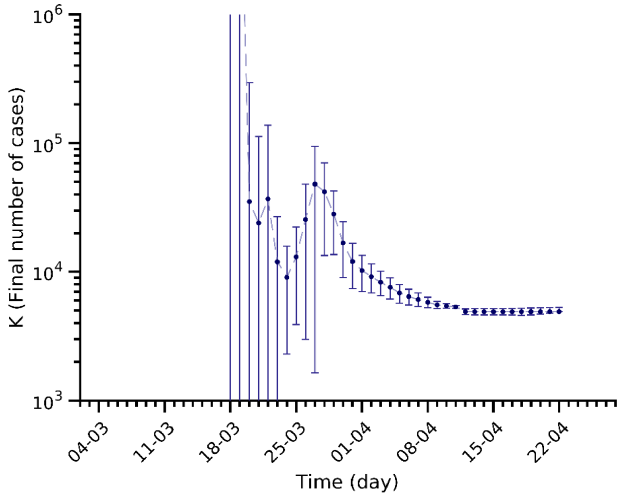


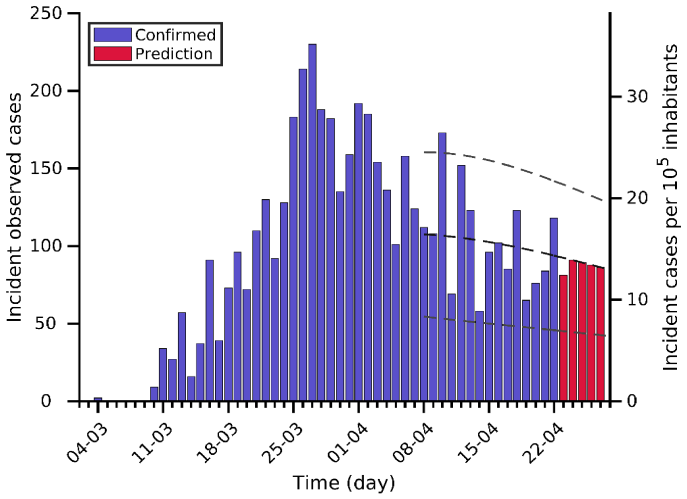
Navarra 22-04-2020. Population: 0.7M. Current cumulated incidence: 749/10^5

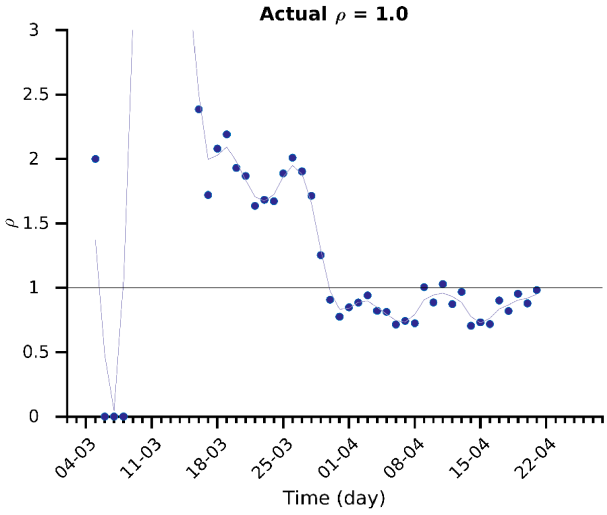


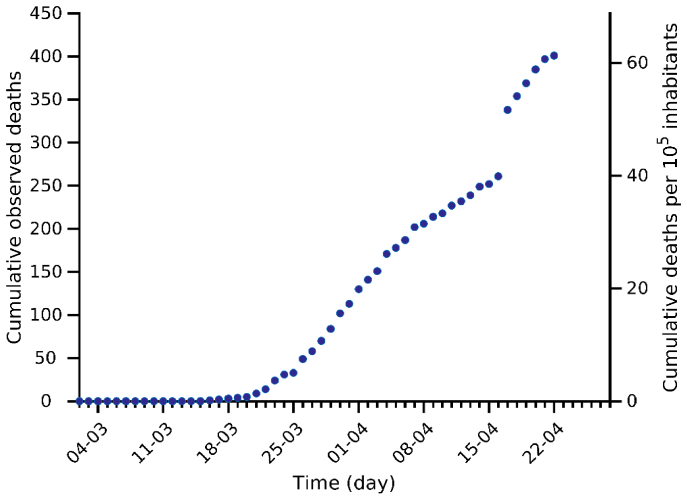


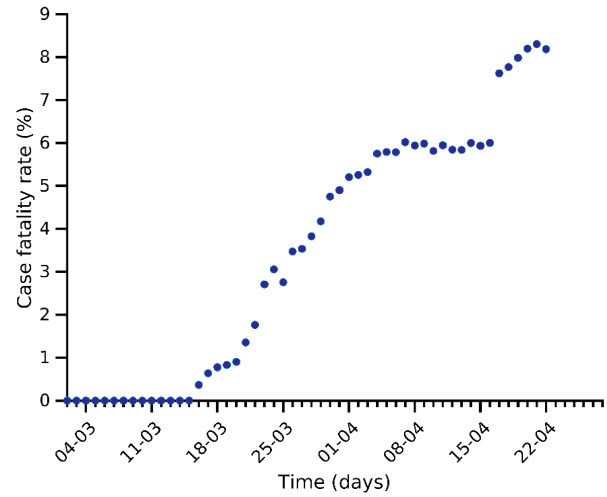




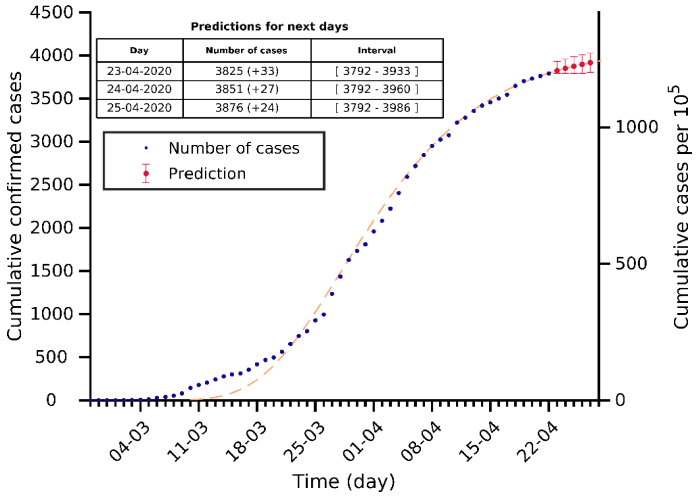


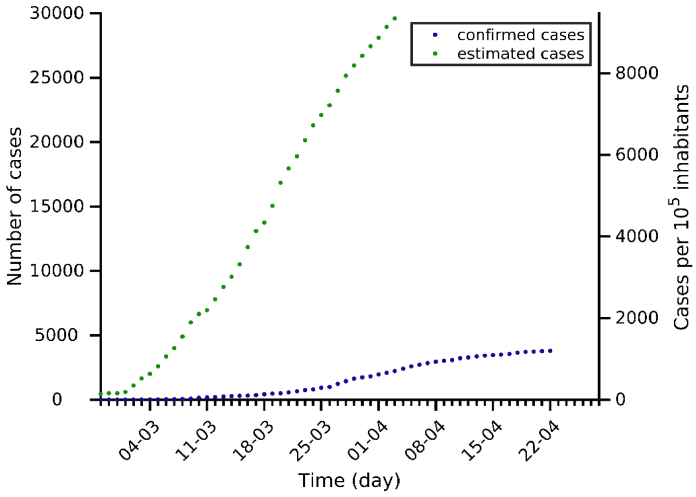


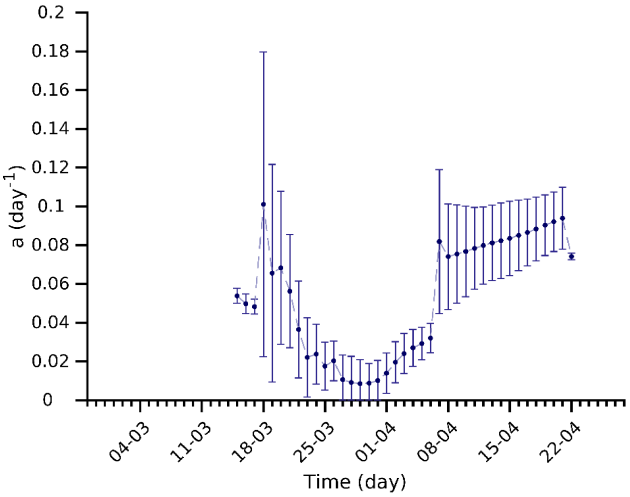


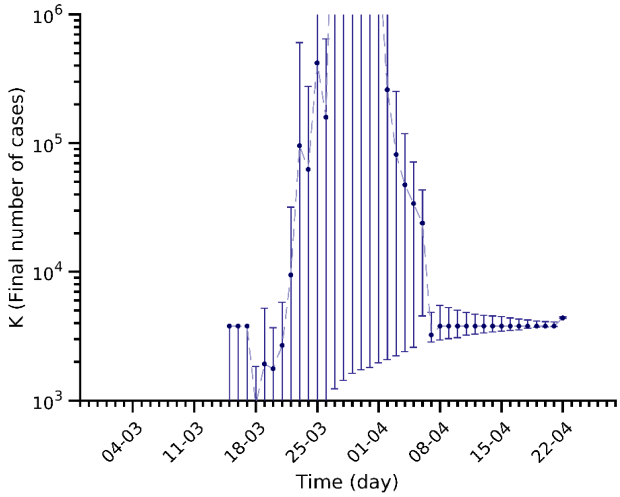


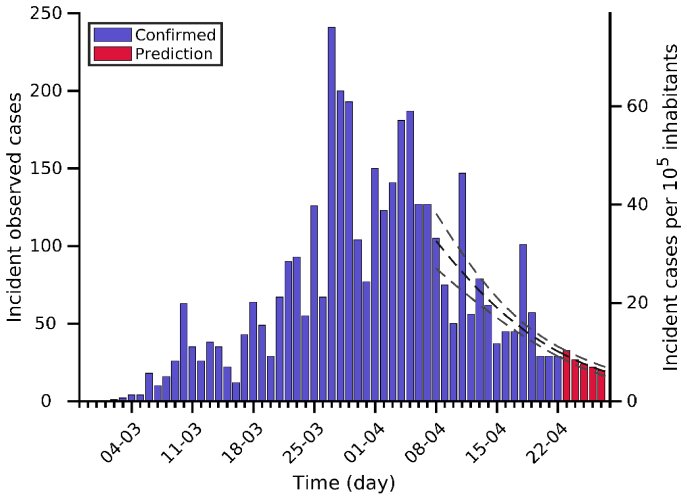
La Rioja 22-04-2020. Population: 0.3M. Current cumulated incidence: 1197/10^5

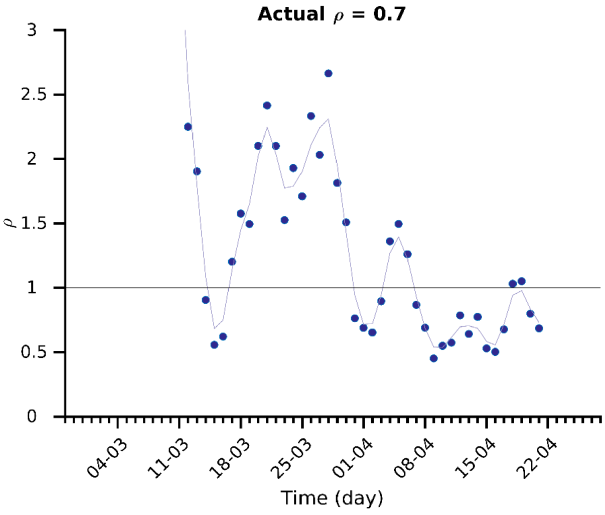


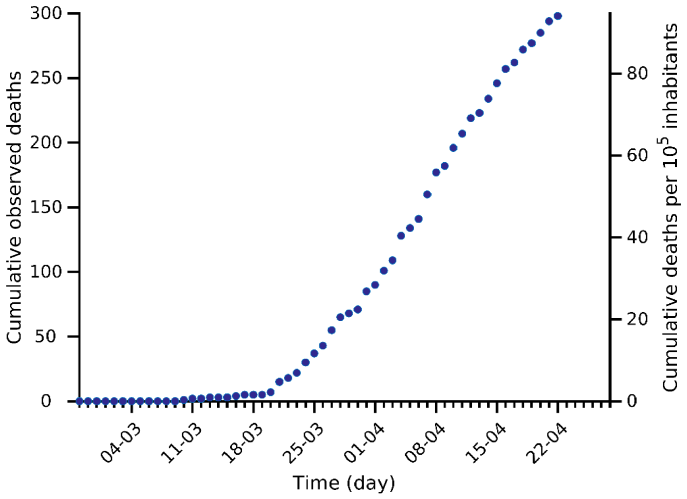


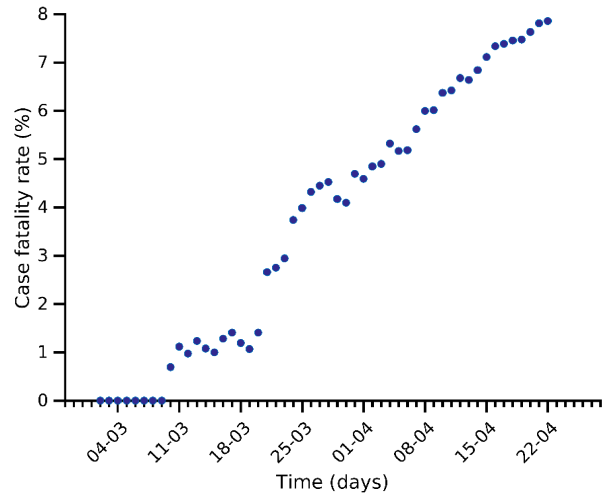




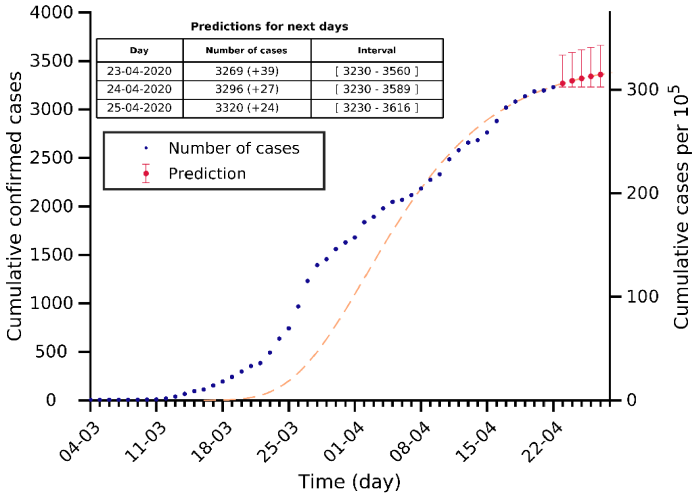


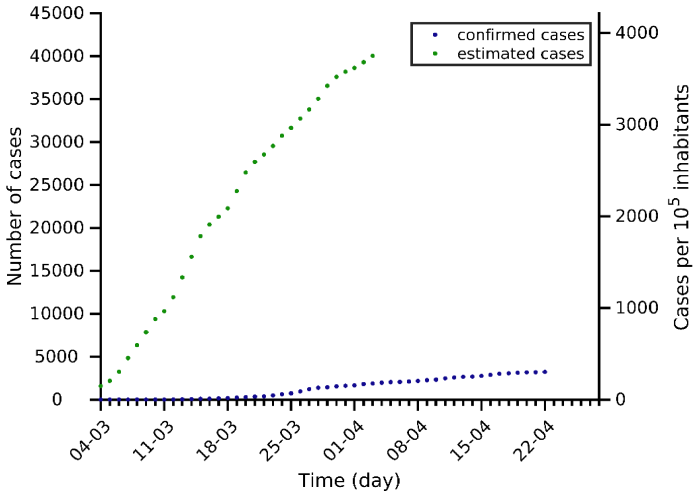


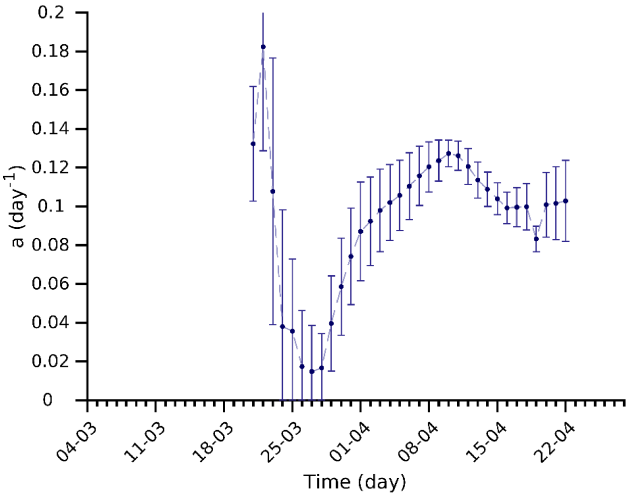


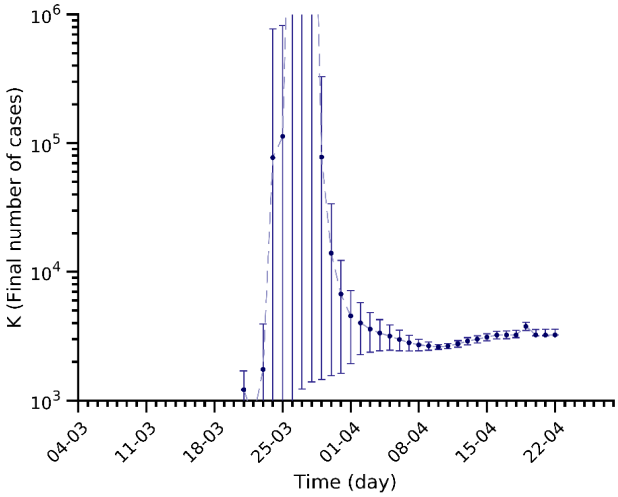


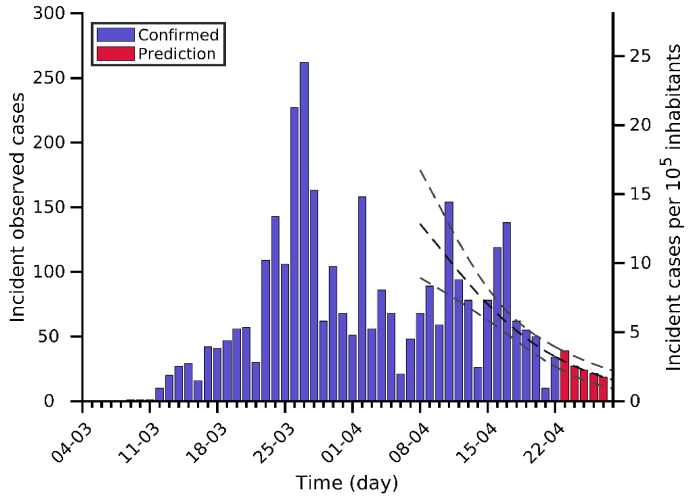
Extremadura 22-04-2020. Population: 1.1M. Current cumulated incidence: 303/10^5

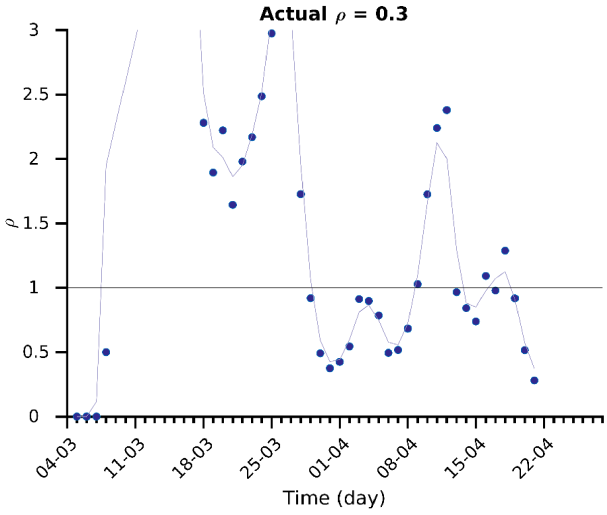


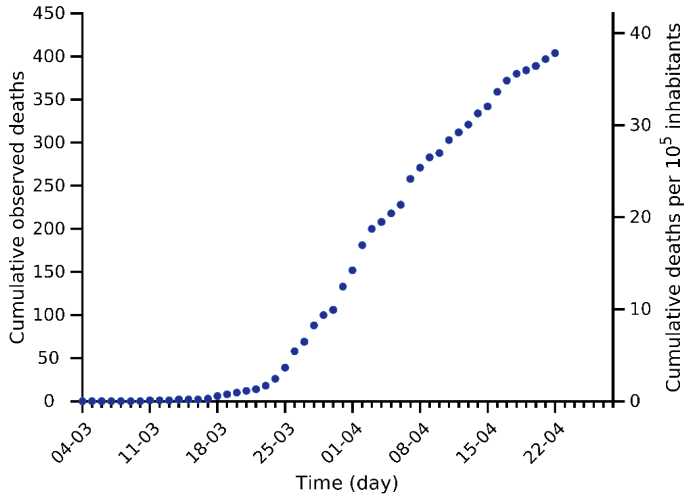


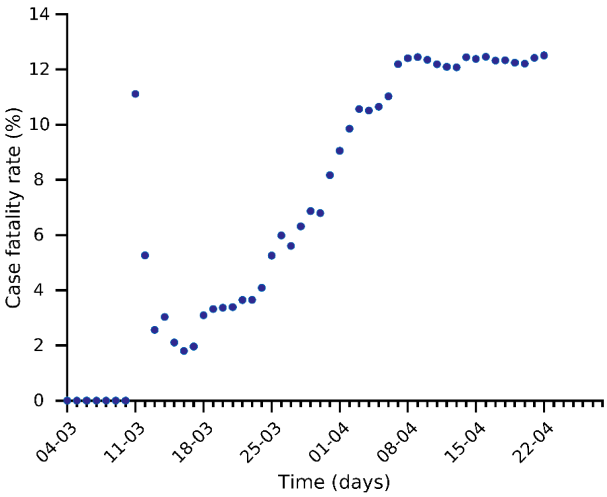




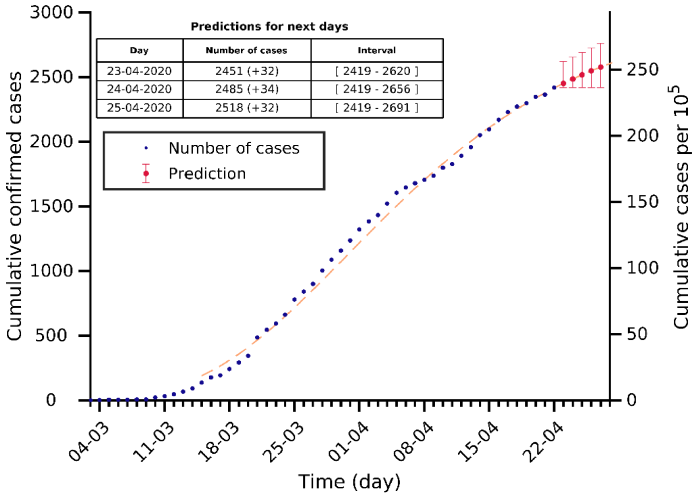


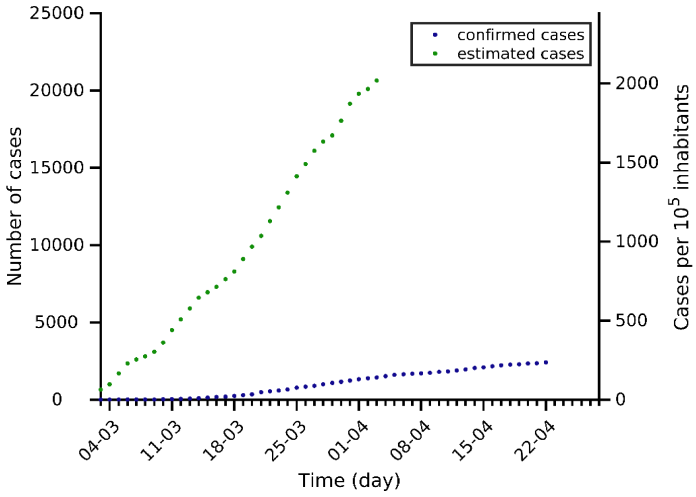


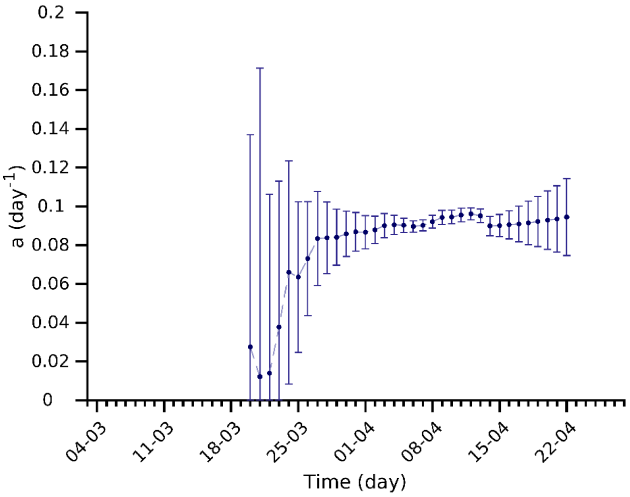


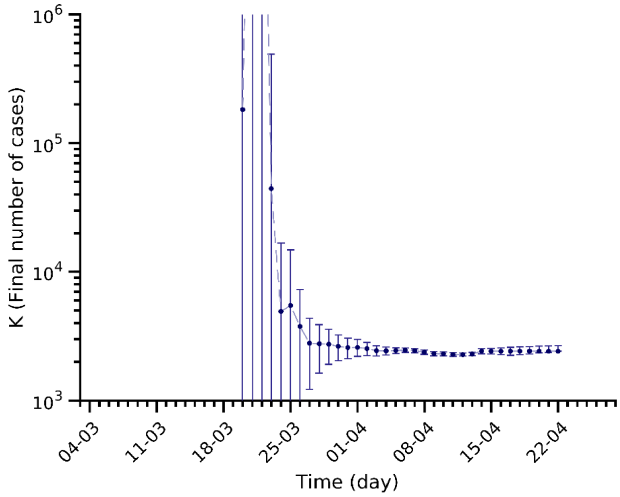


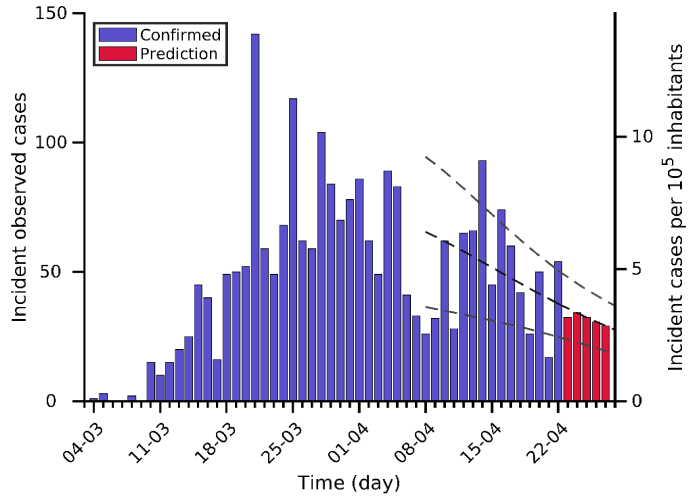
Asturias 22-04-2020. Population: 1.0M. Current cumulated incidence: 237/10⁵

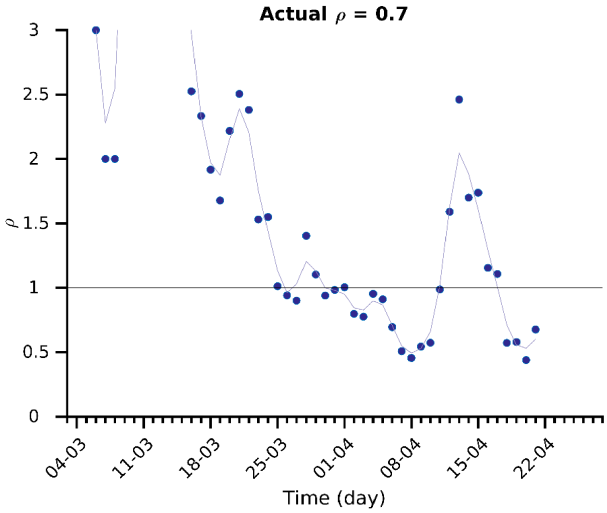


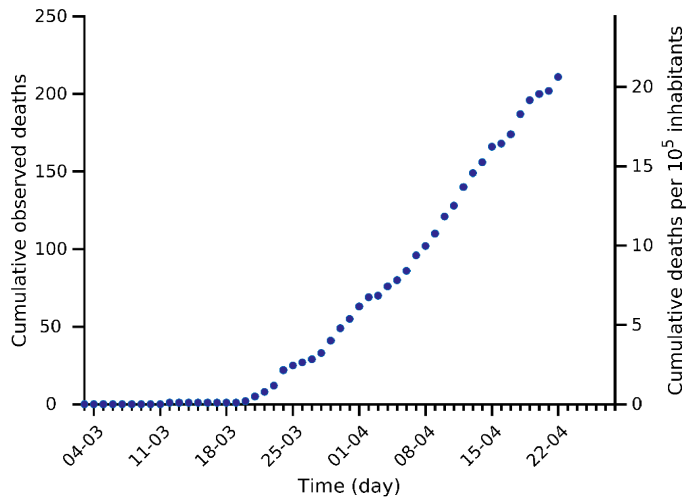


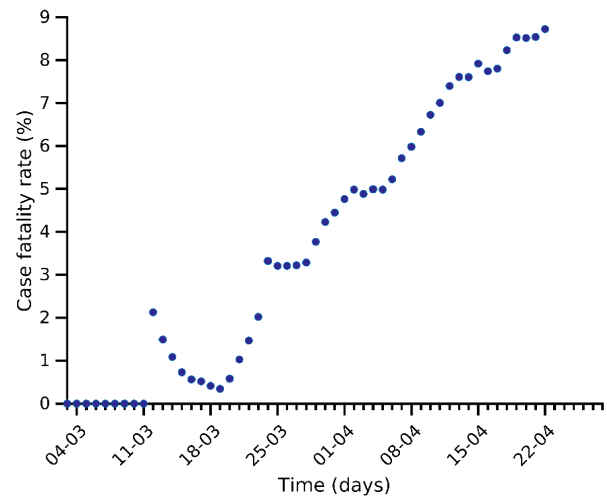




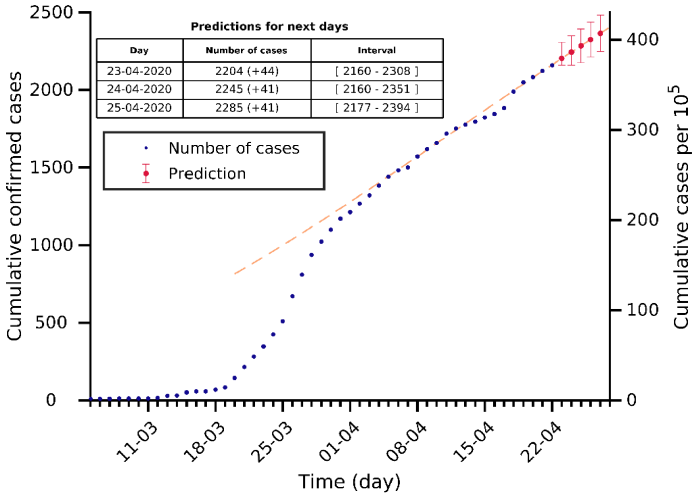


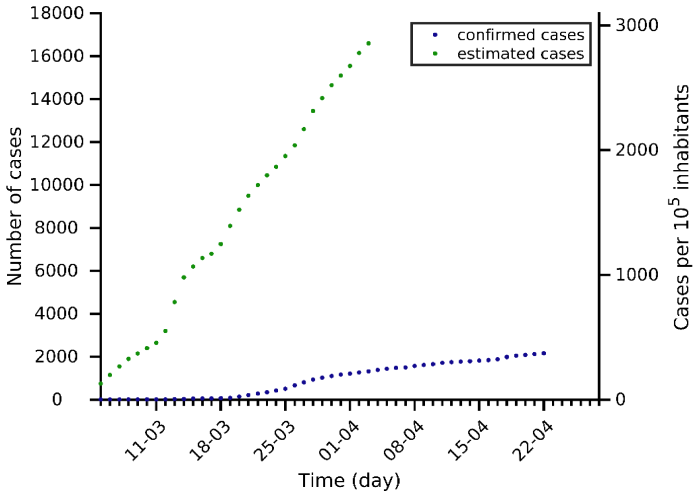


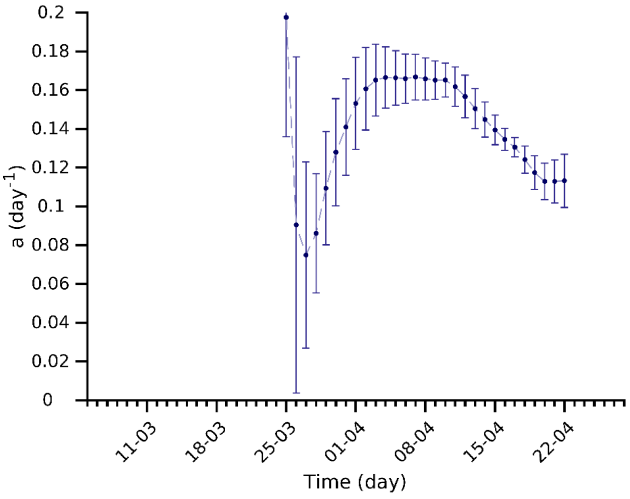


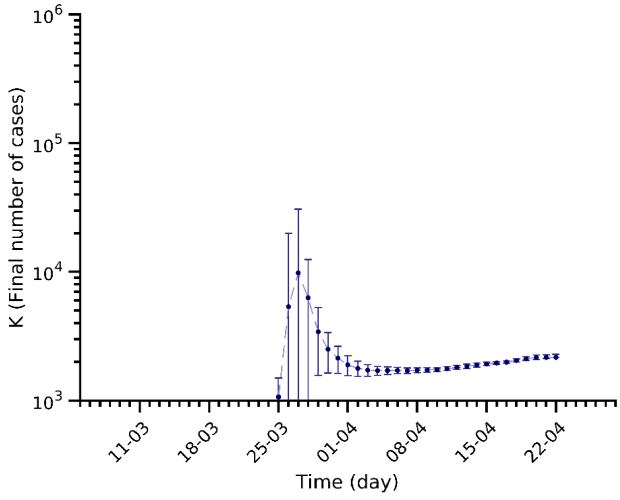


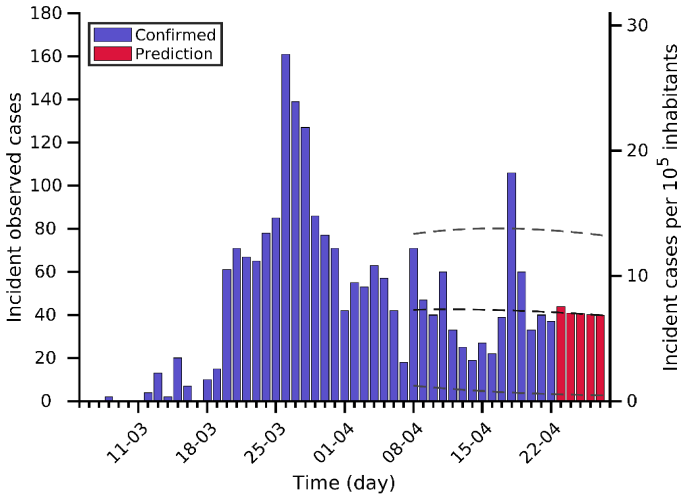
Cantabria 22-04-2020. Population: 0.6M. Current cumulated incidence: 372/10⁵

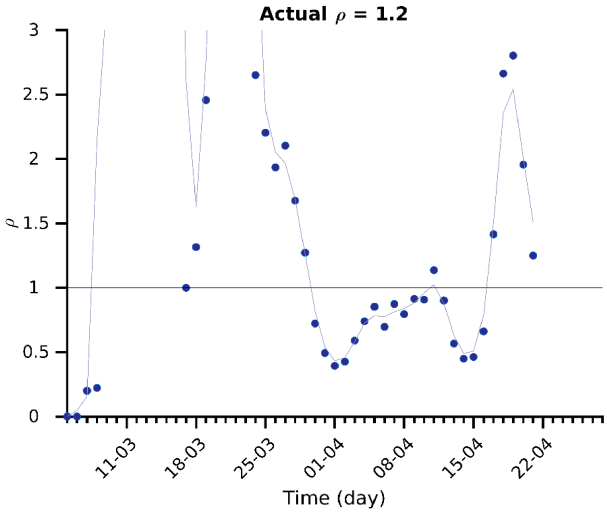


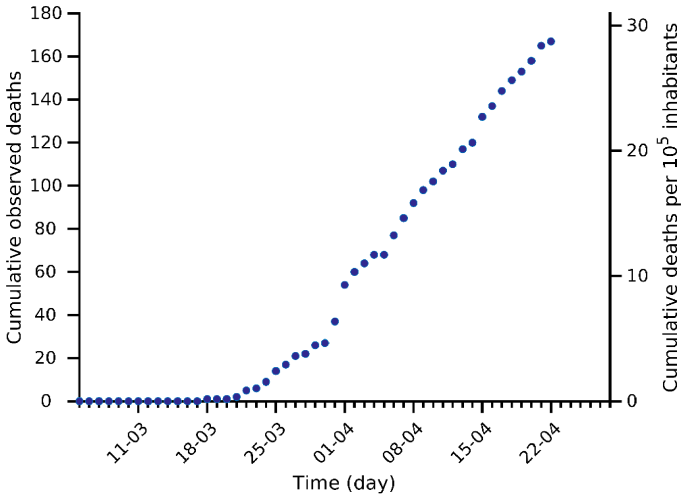


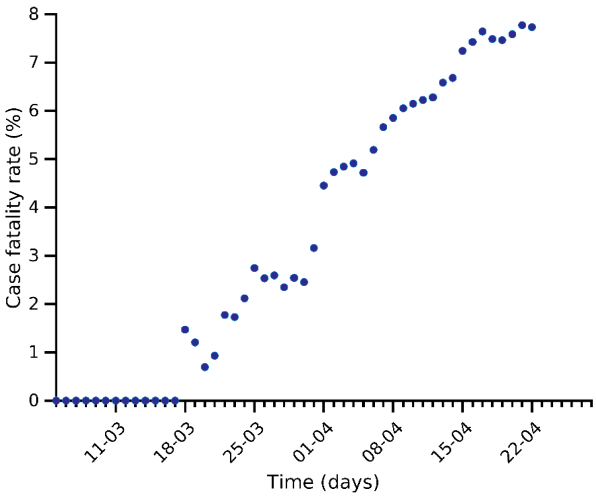




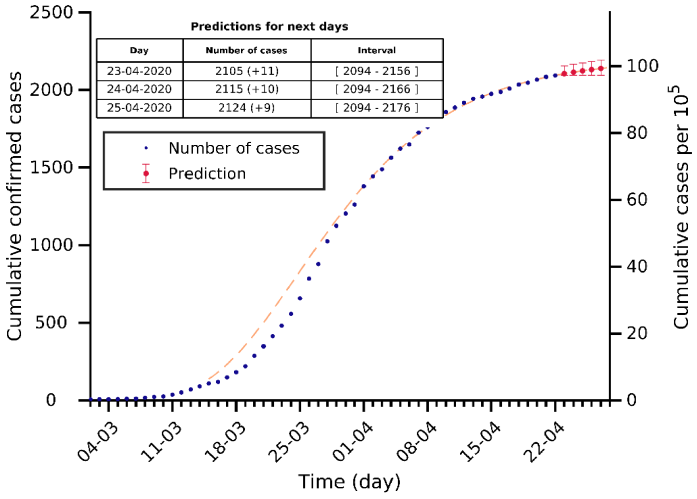


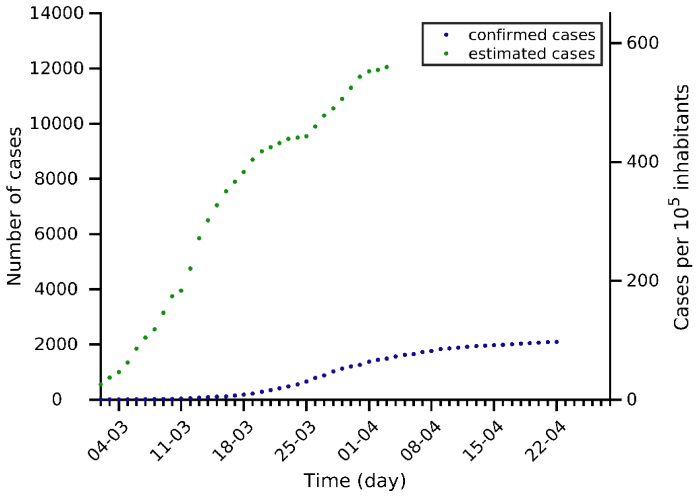


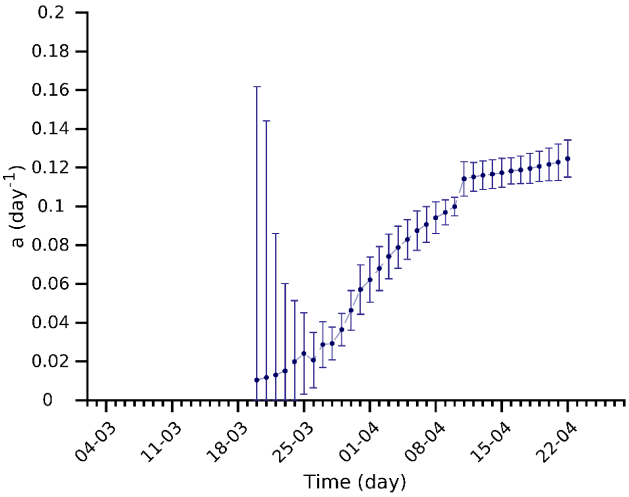


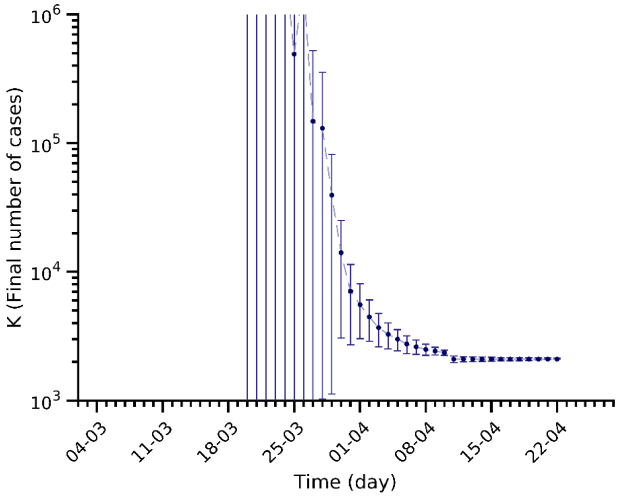


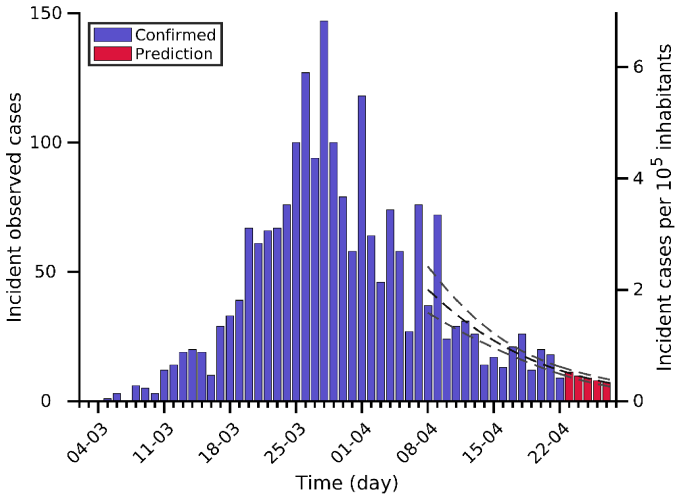
Canarias 22-04-2020. Population: 2.2M. Current cumulated incidence: 97/10⁵

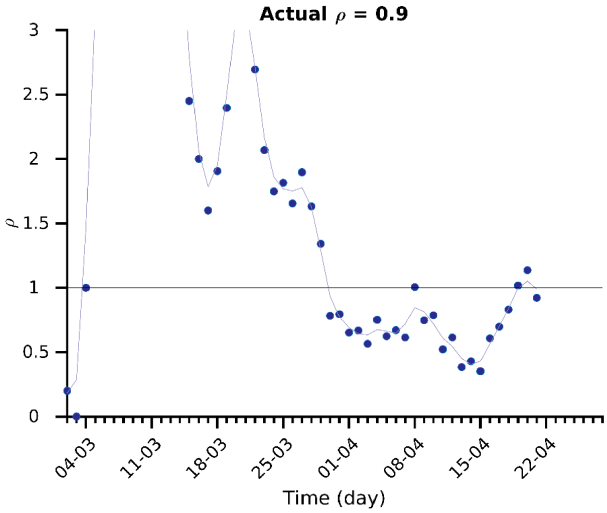


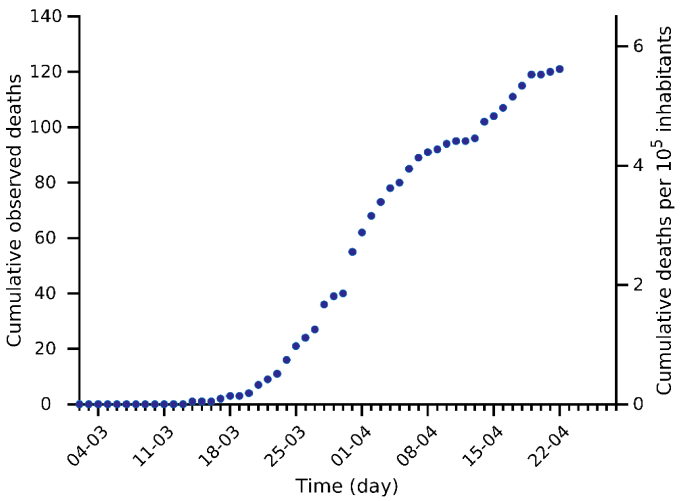


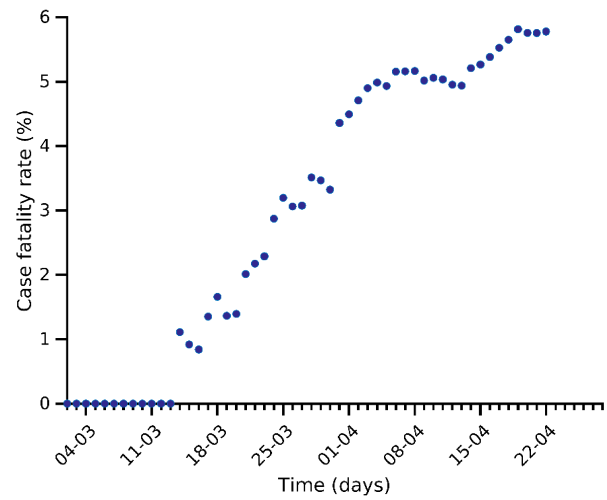




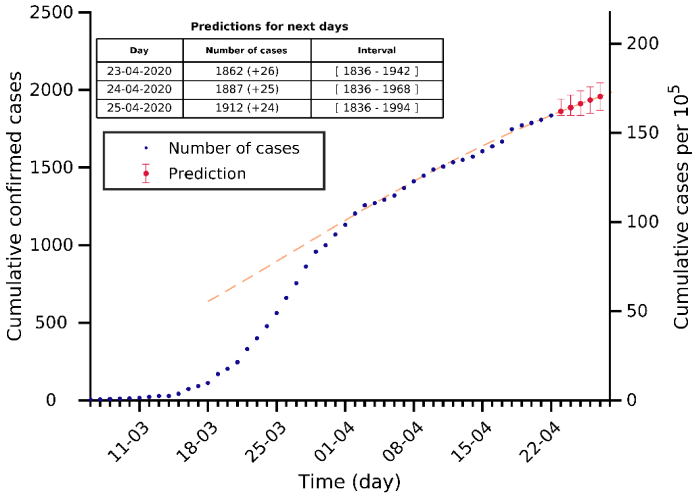


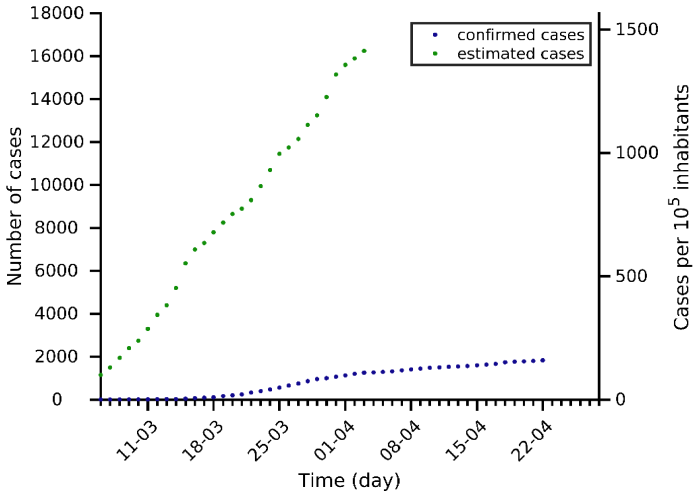


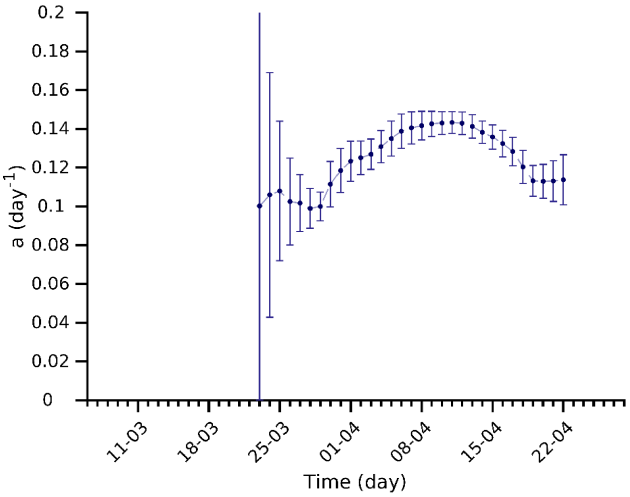


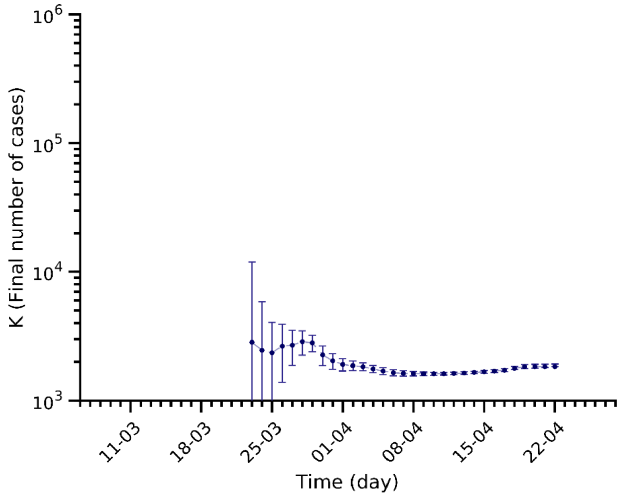


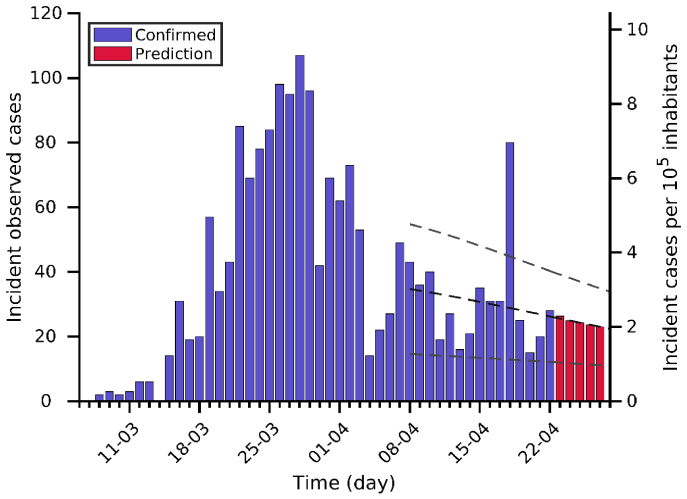
Baleares 22-04-2020. Population: 1.1M. Current cumulated incidence: $160/10^5$

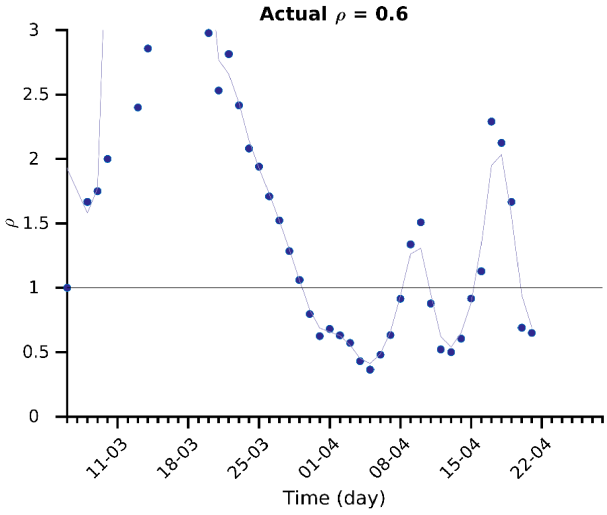


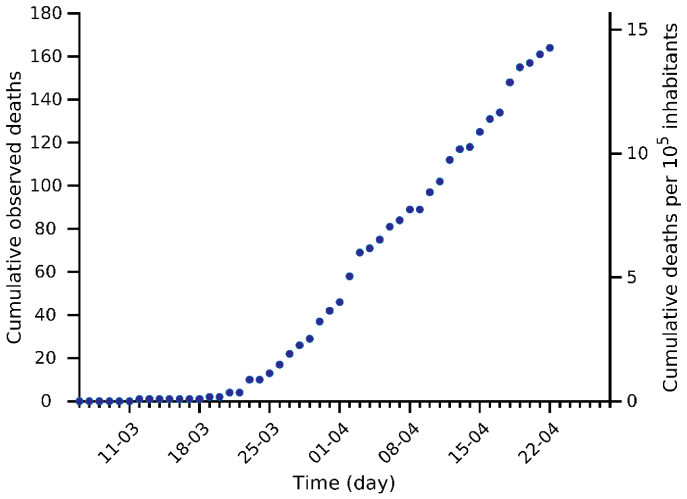


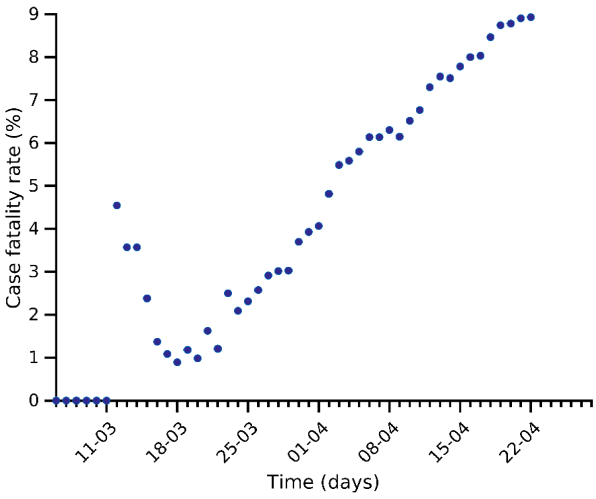




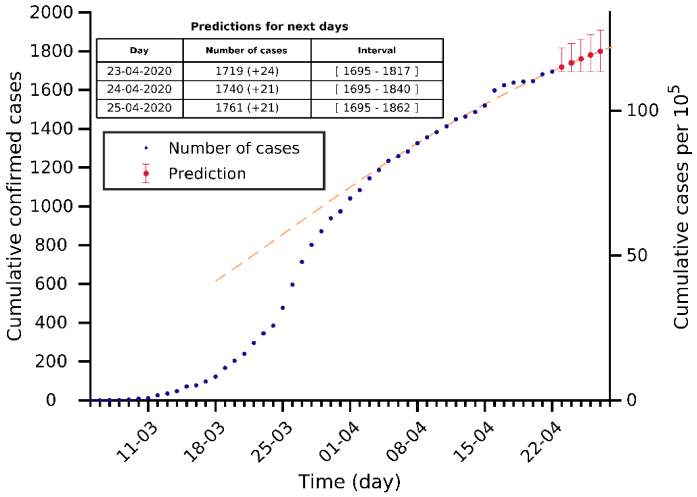


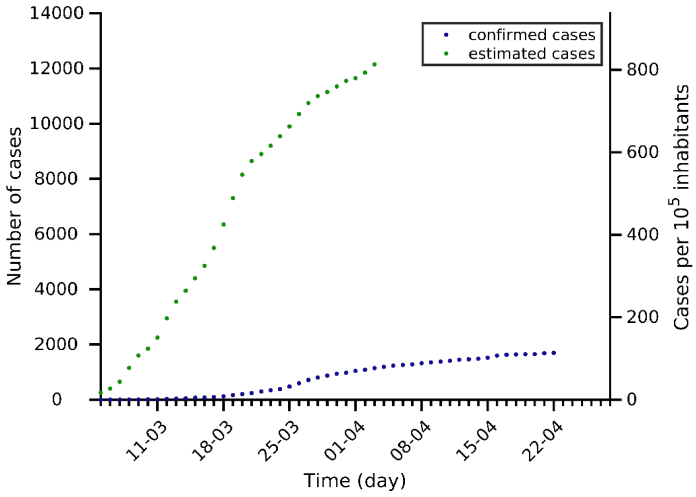


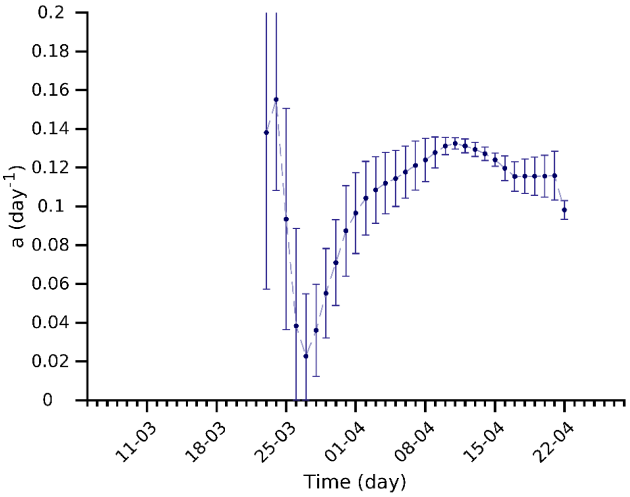


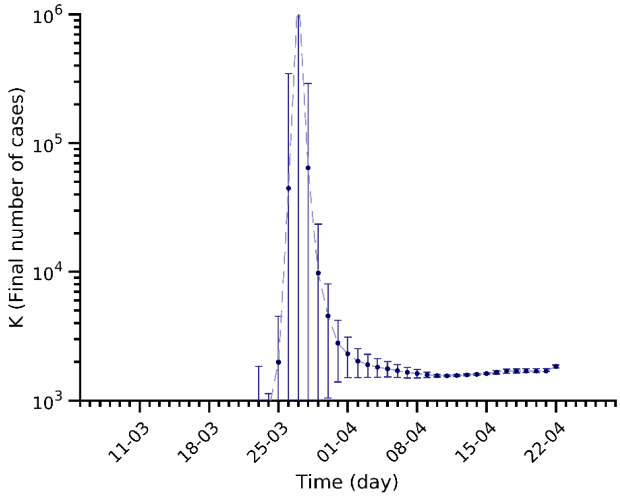


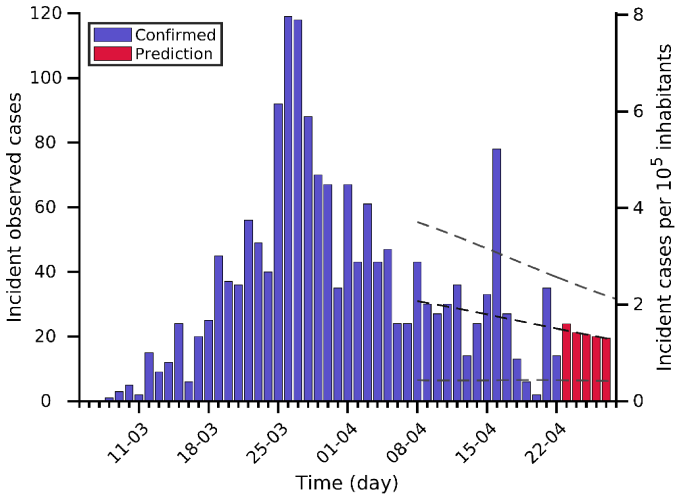
Murcia 22-04-2020. Population: 1.5M. Current cumulated incidence: 113/10^5

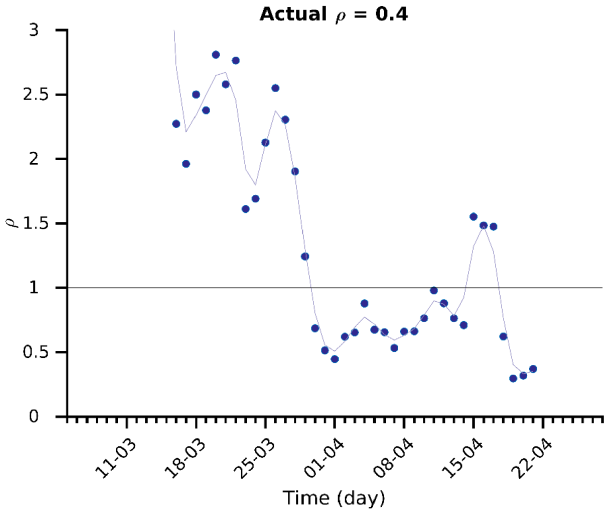


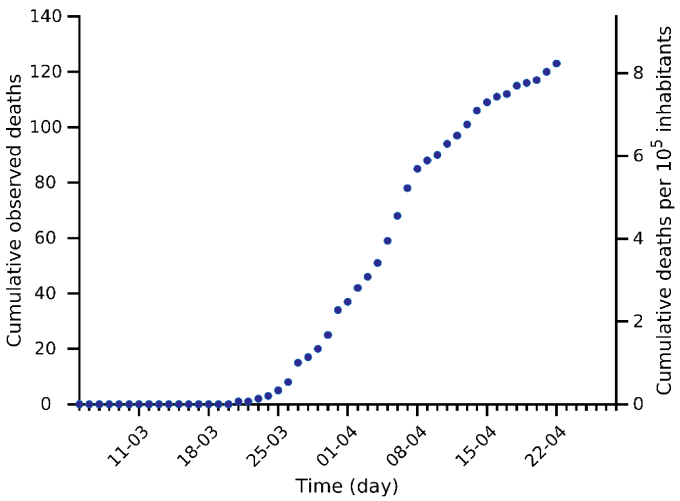


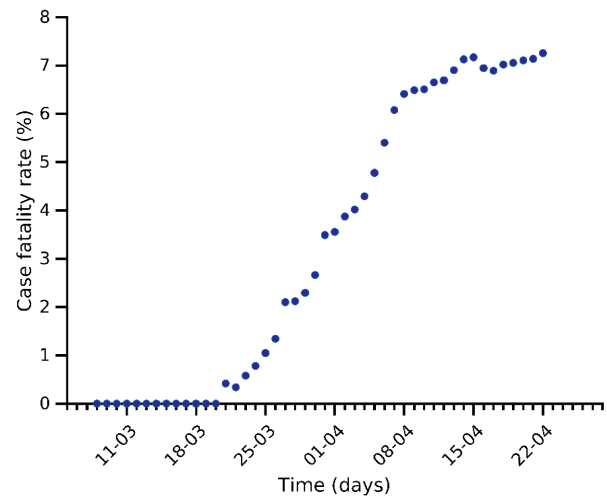








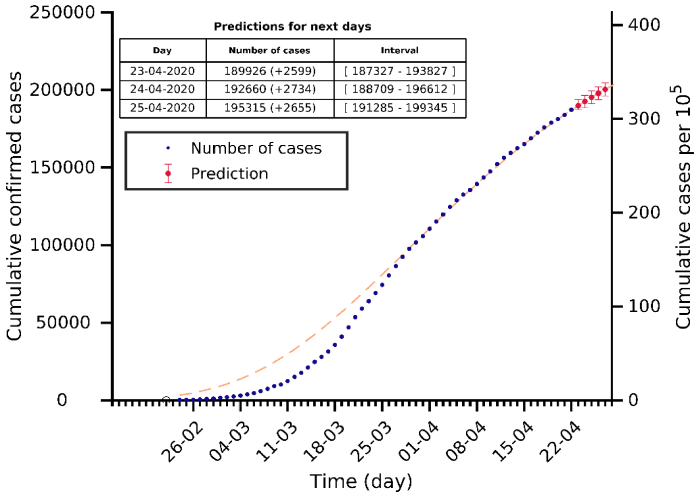


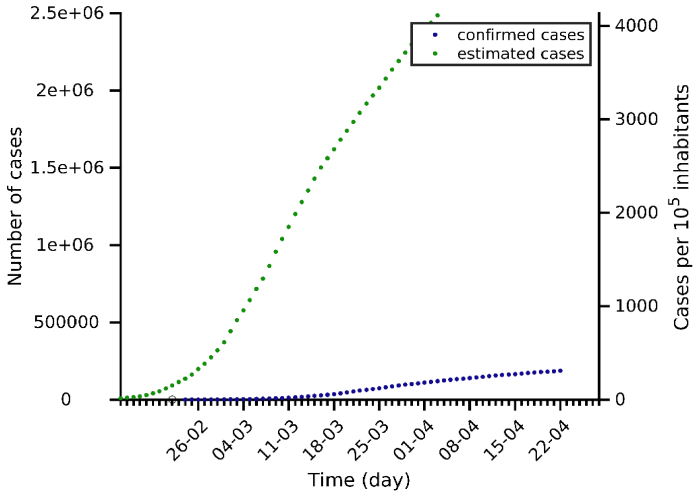


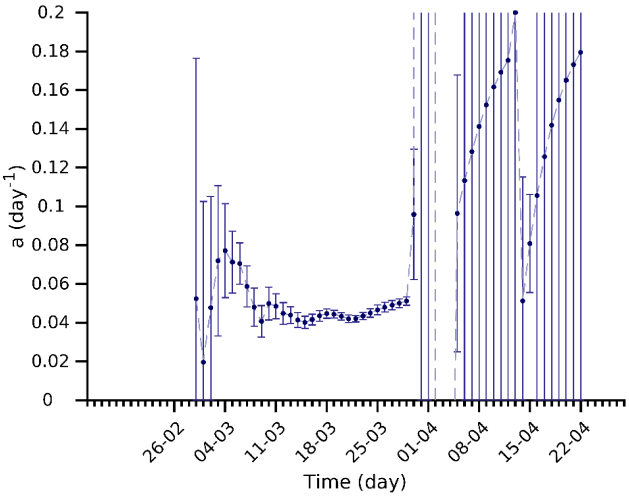
(4) Analysis and prediction of COVID-19 for Italy and its regions

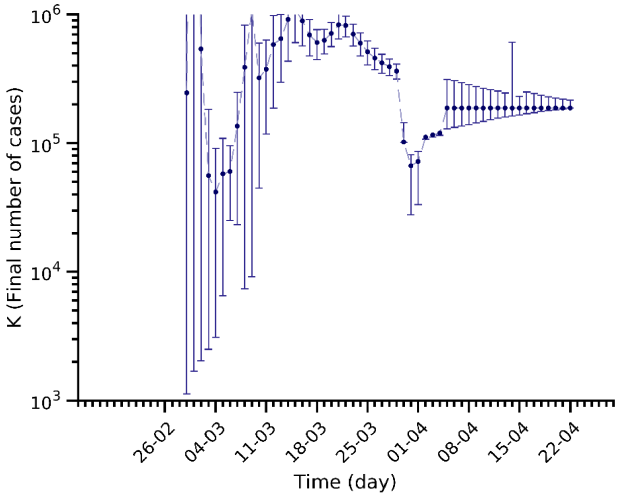
Data obtained from: https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale

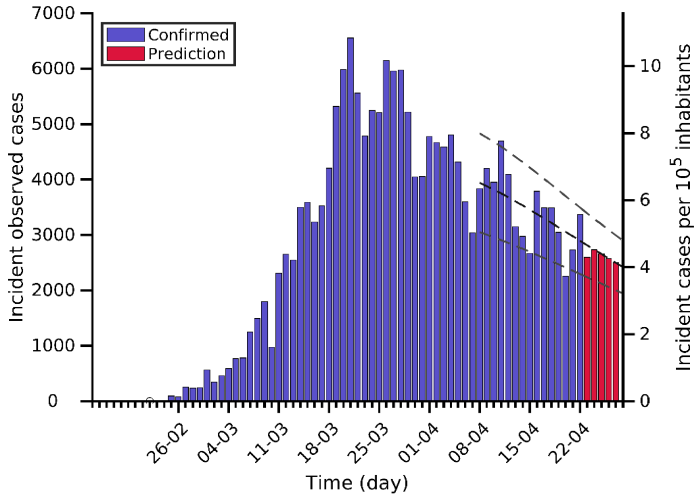
Italy 22-04-2020. Population: 60.5M. Current cumulated incidence: $310/10^5$

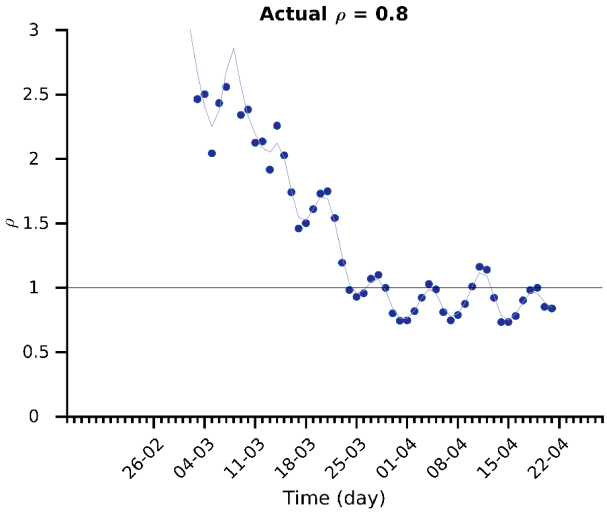


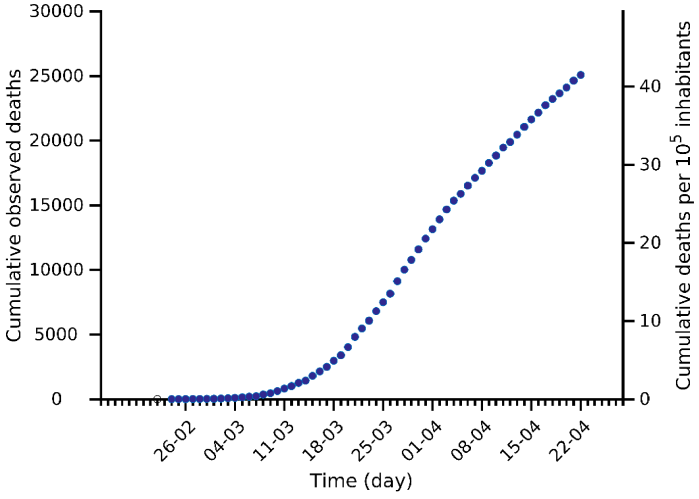


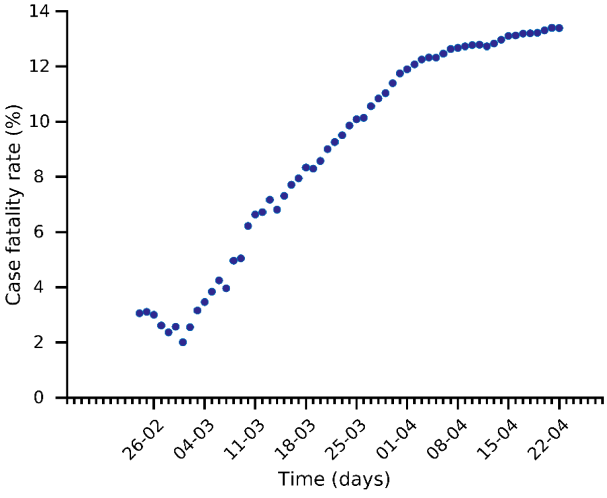




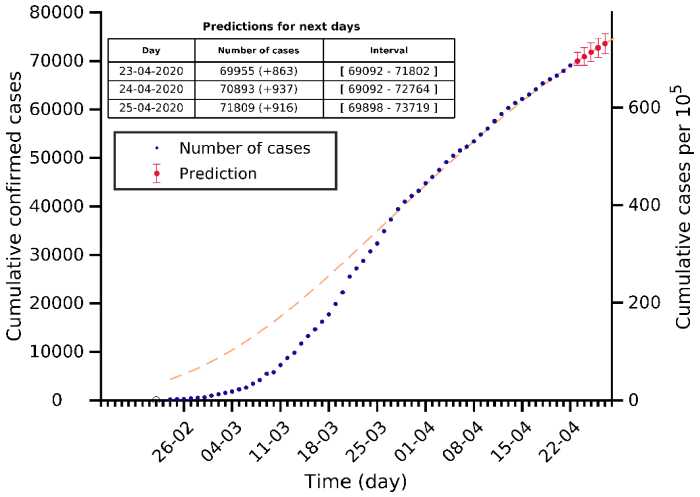


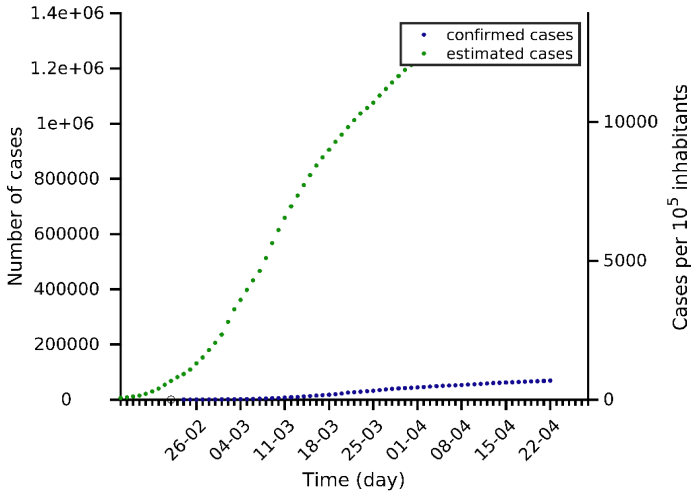


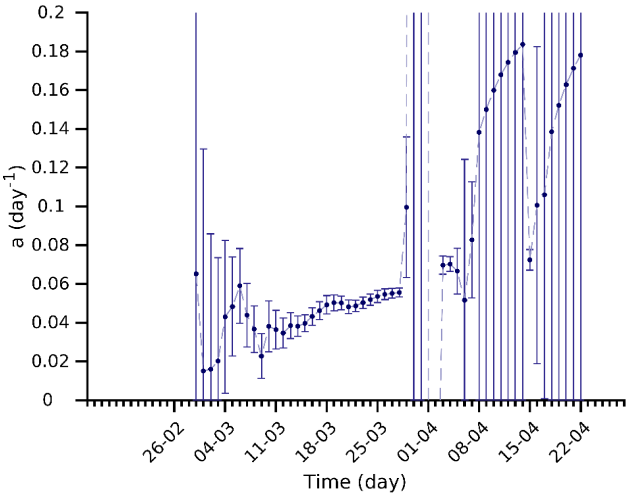


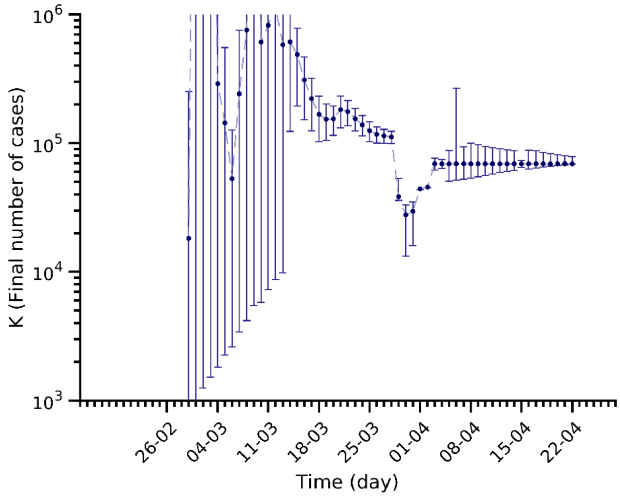


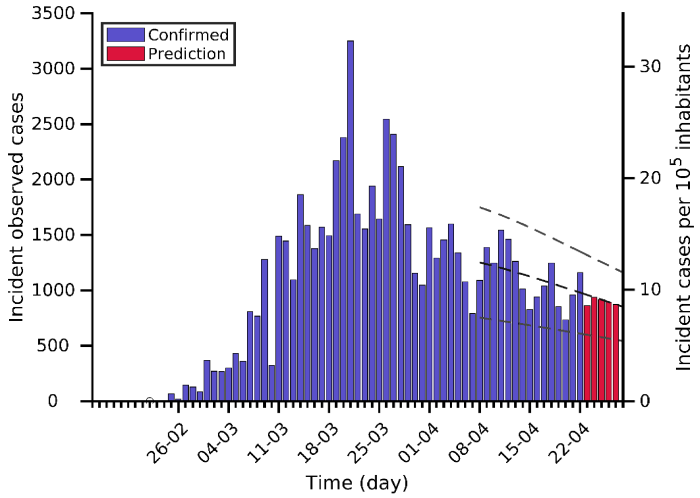
Lombardia 22-04-2020. Population: 10.1M. Current cumulated incidence: 687/10^5

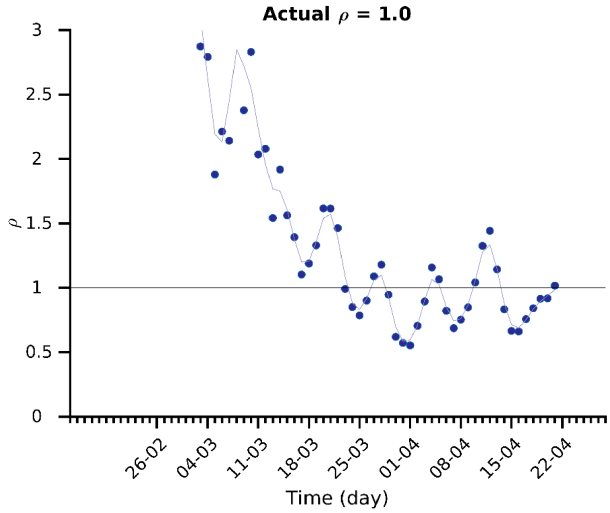


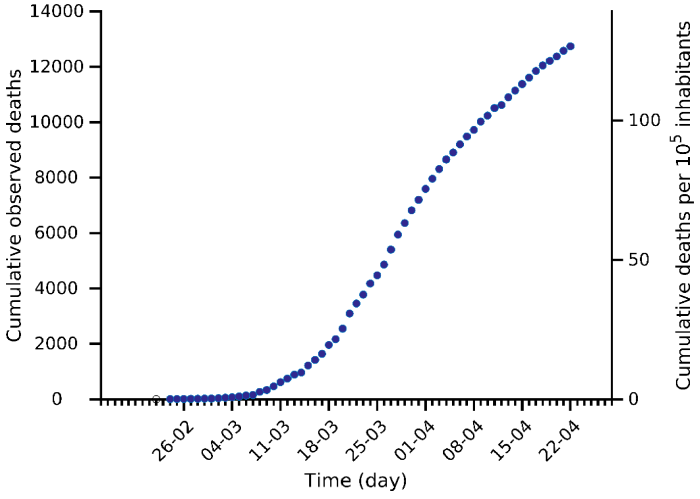


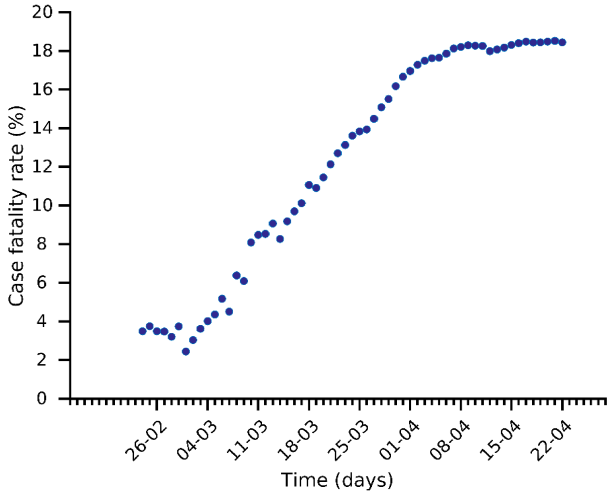




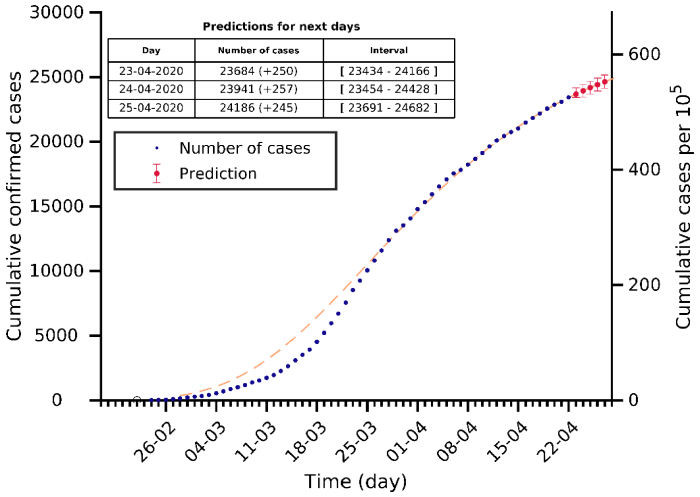


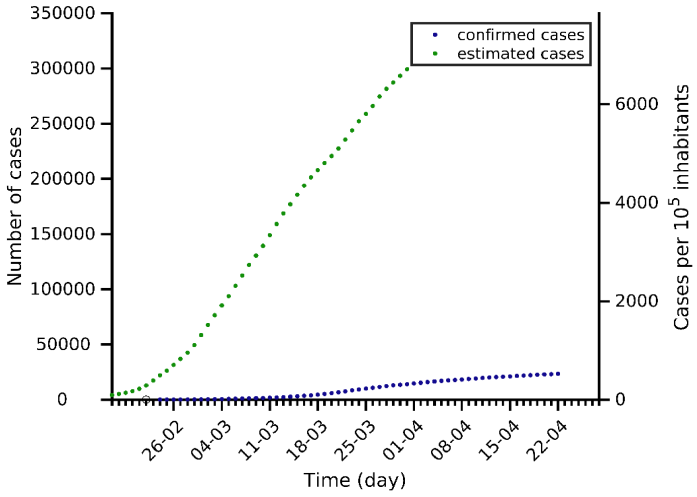


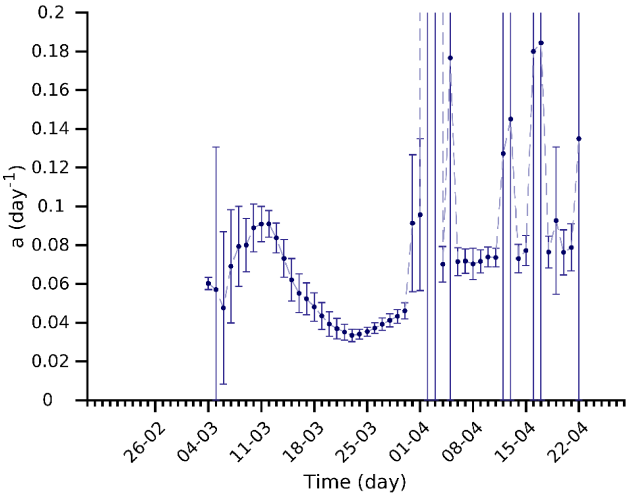


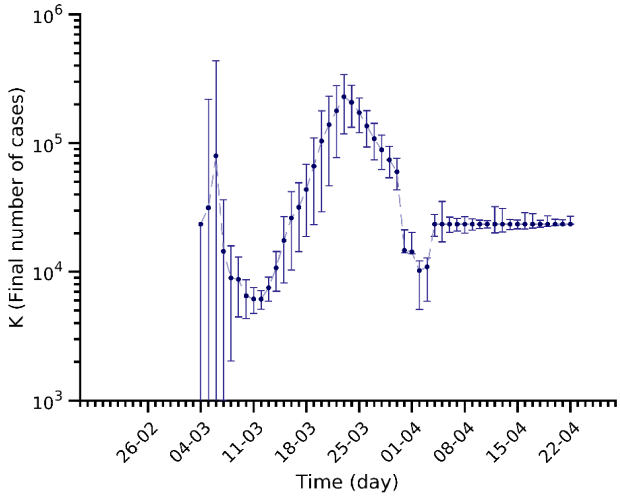


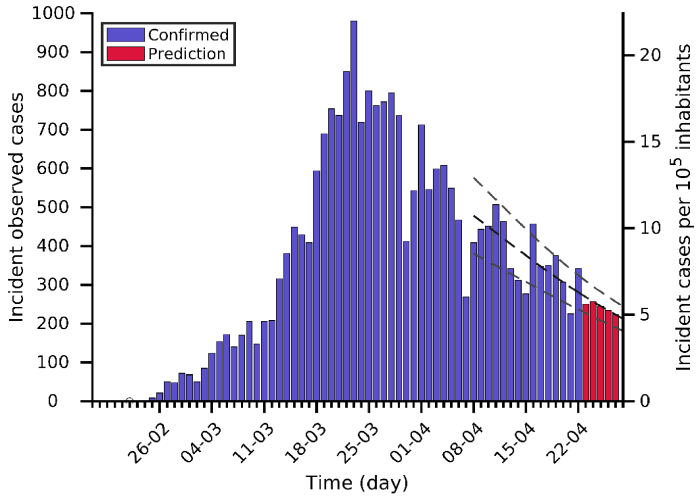
Emilia Romagna 22-04-2020. Population: 4.5M. Current cumulated incidence: 526/1

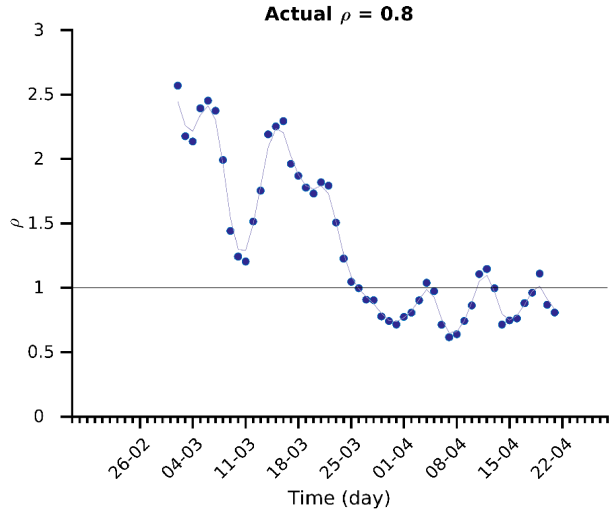


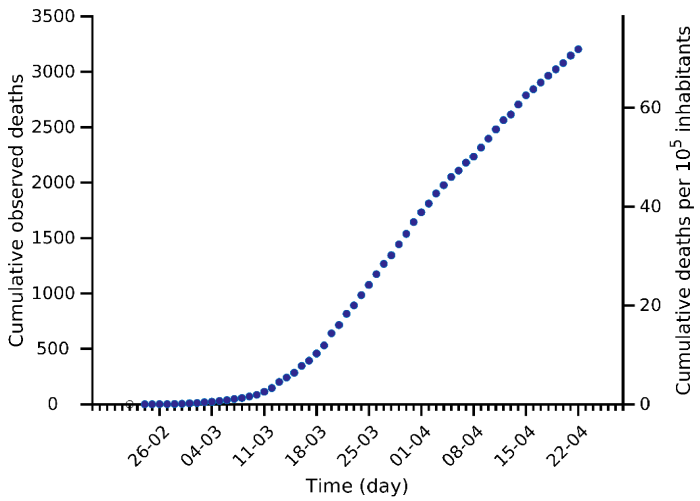


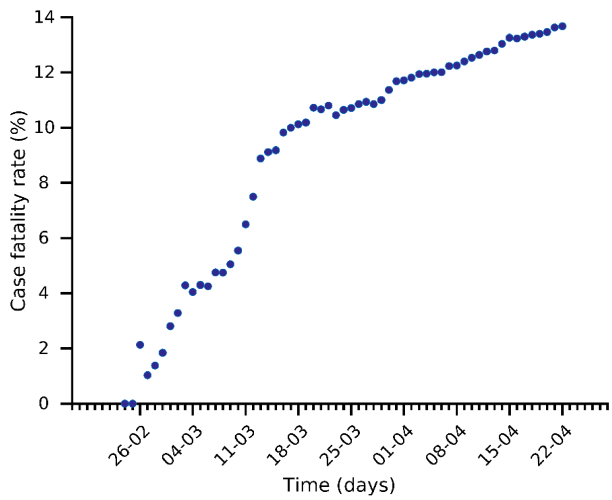




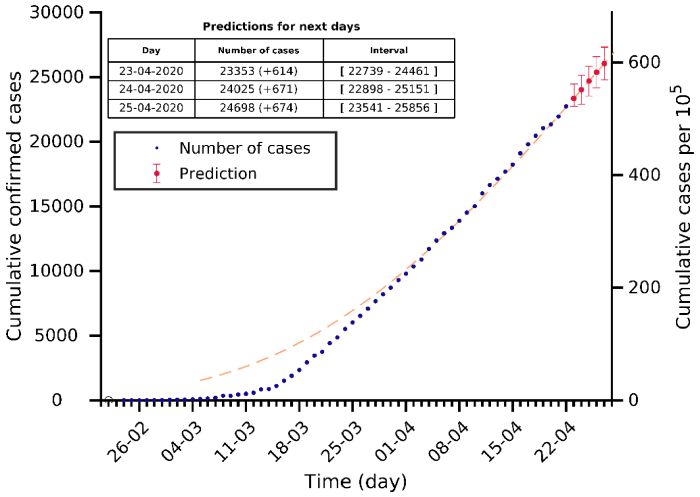


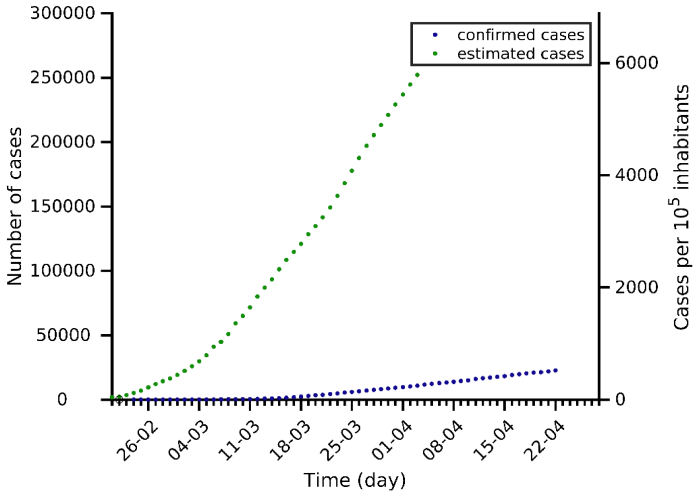


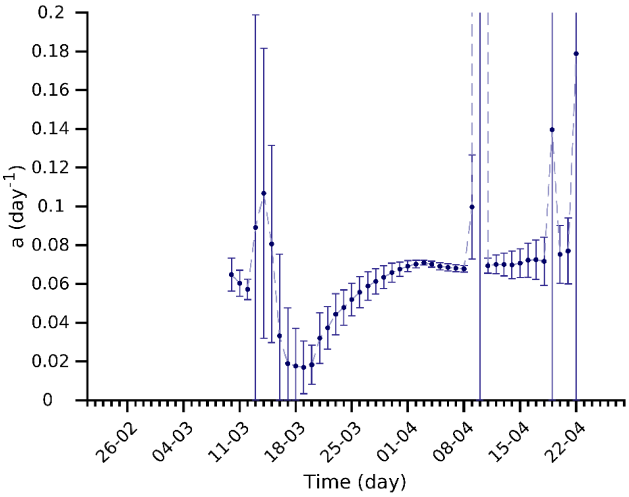


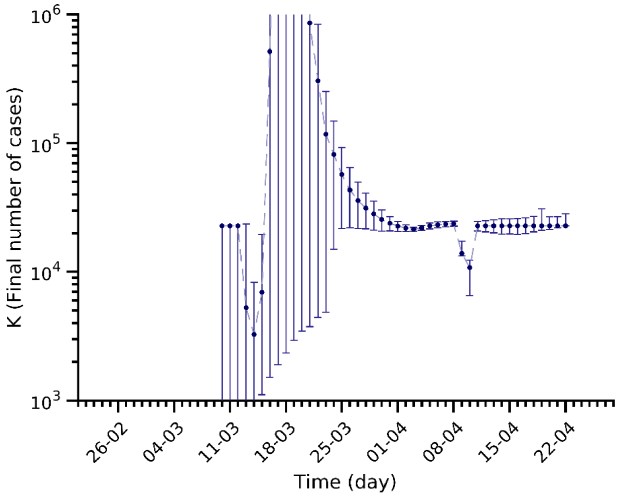


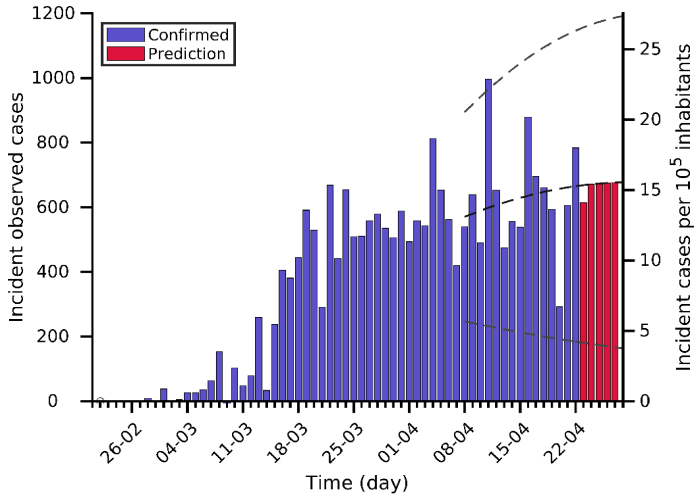
Piemonte 22-04-2020. Population: 4.4M. Current cumulated incidence: 522/10⁵

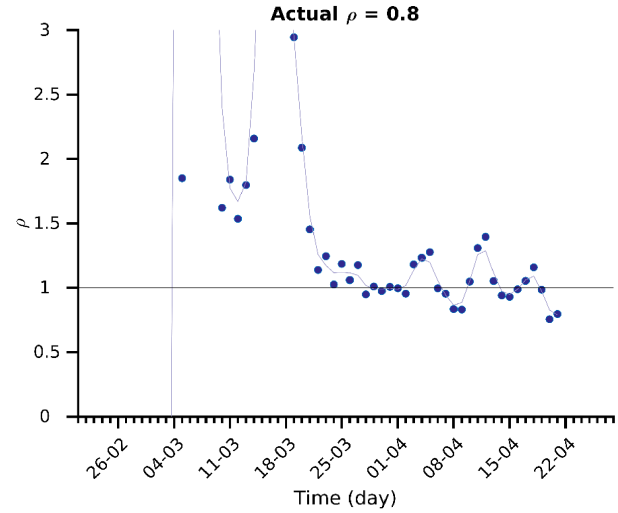


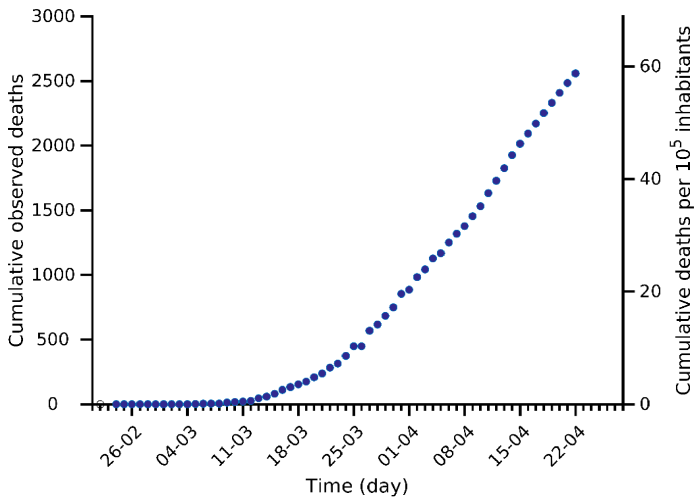


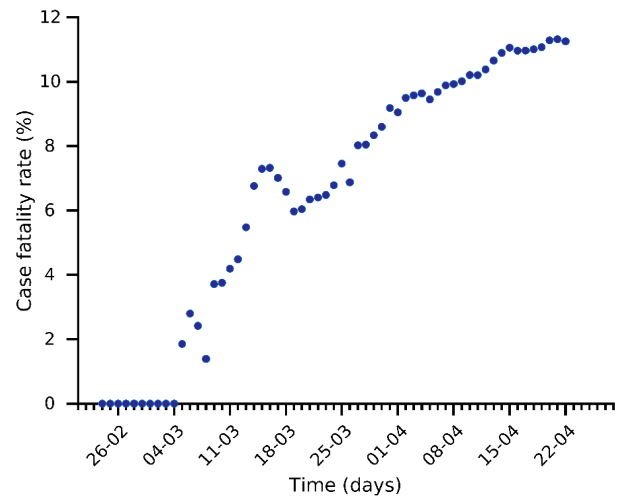




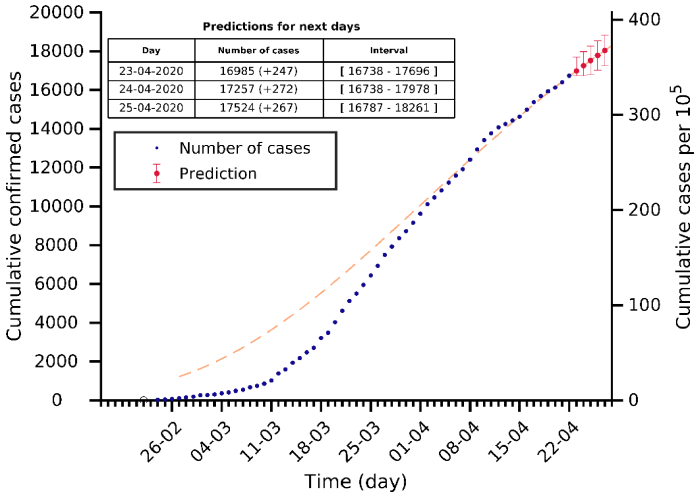


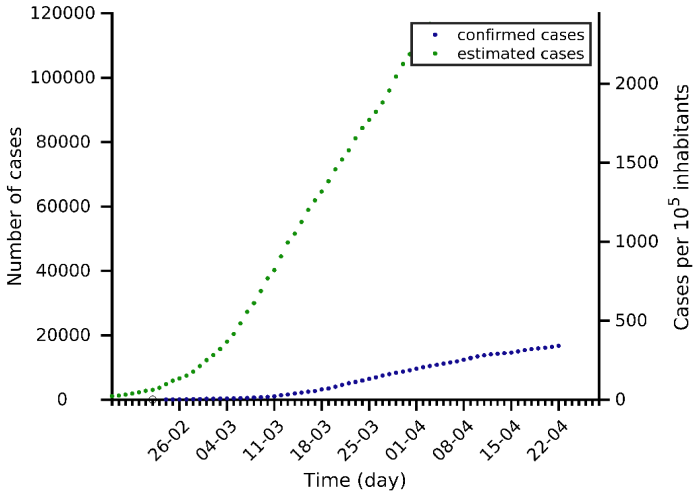


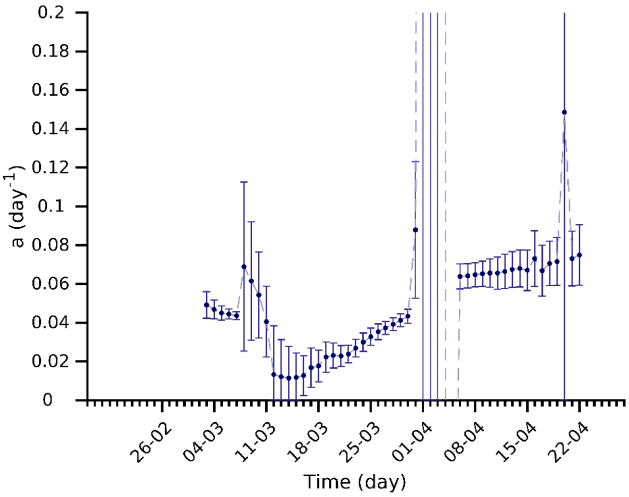


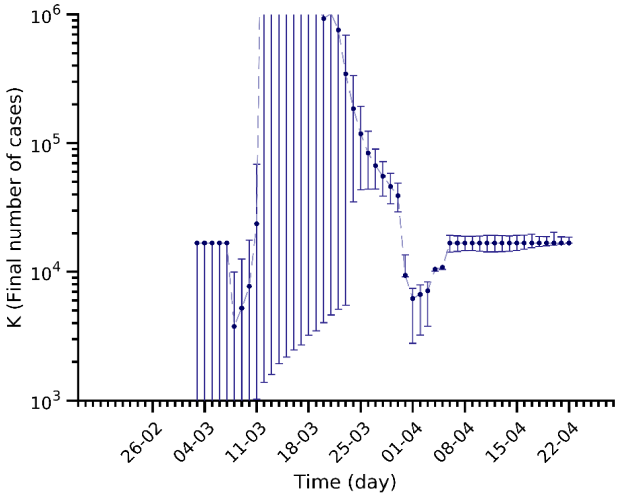


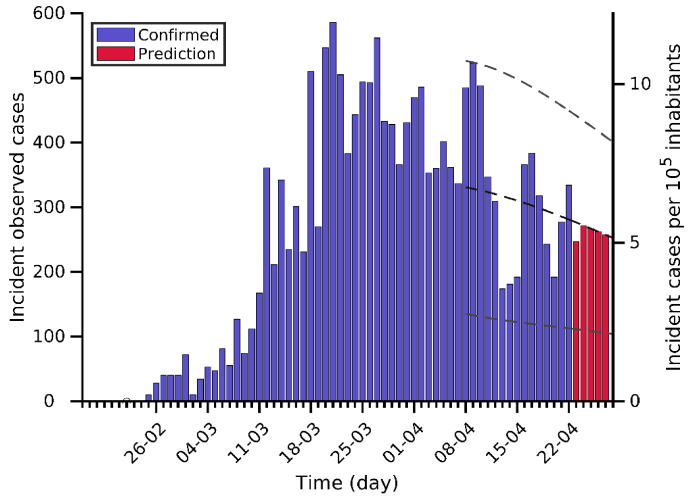
Veneto 22-04-2020. Population: 4.9M. Current cumulated incidence: 341/10⁵

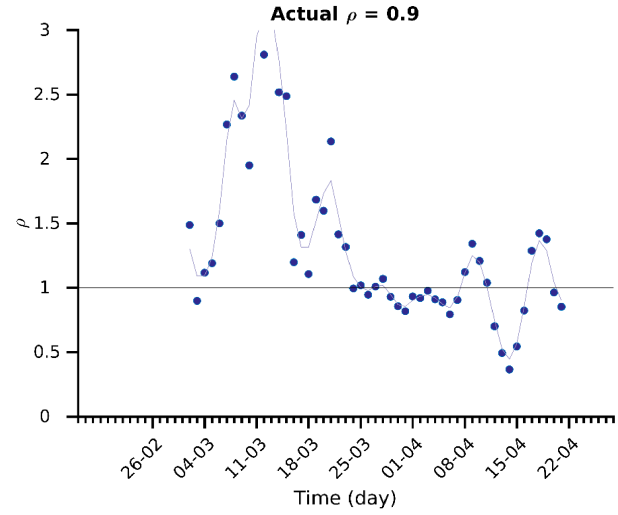


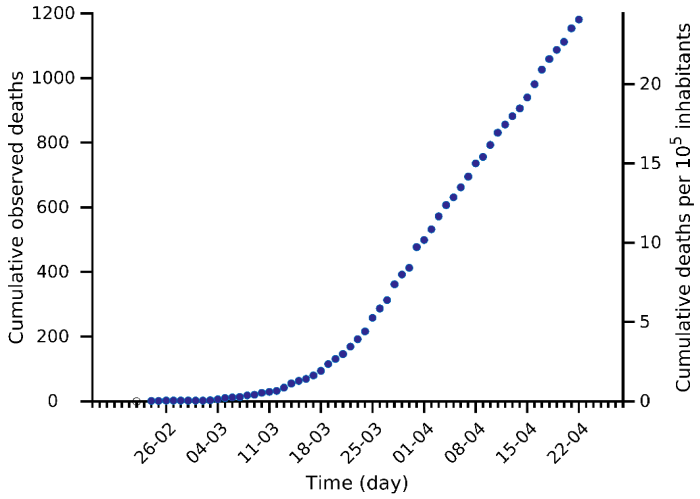


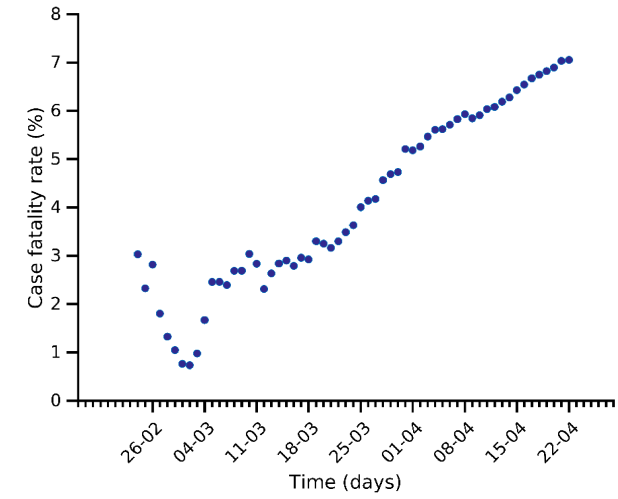




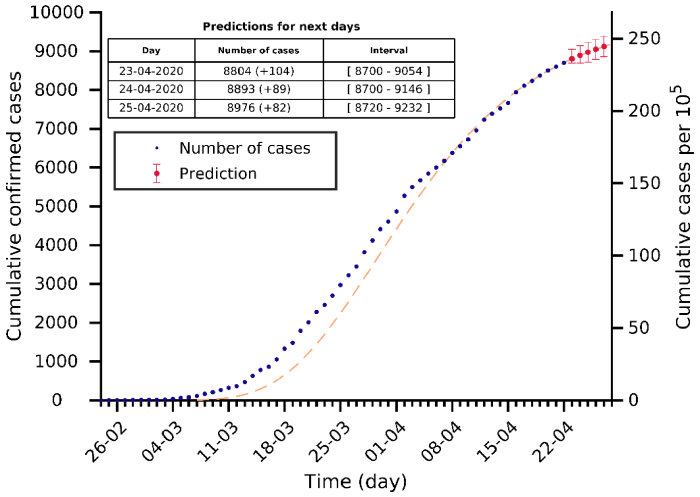


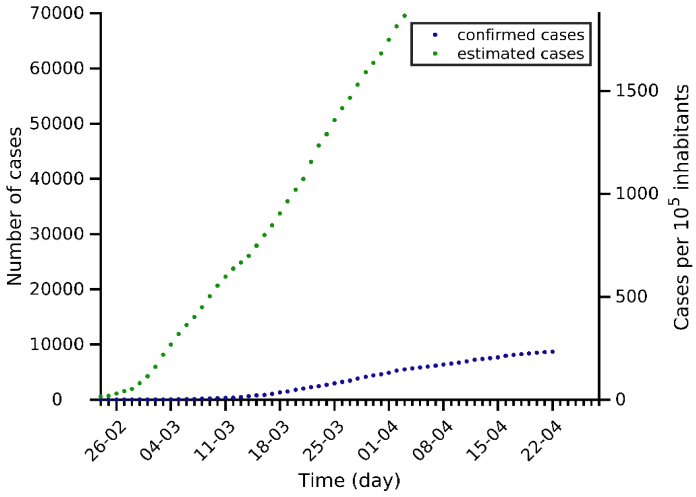


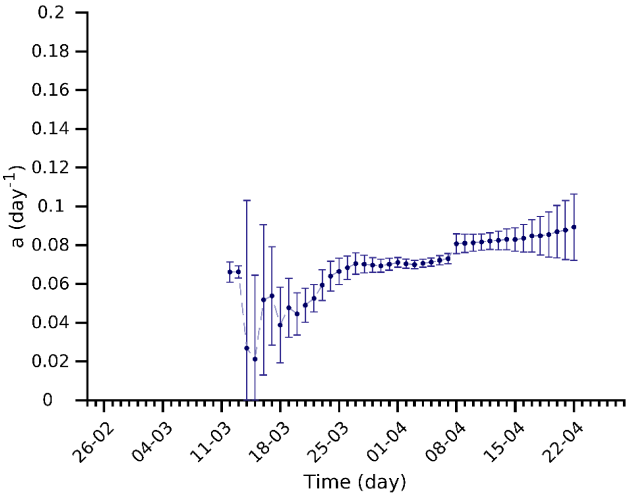


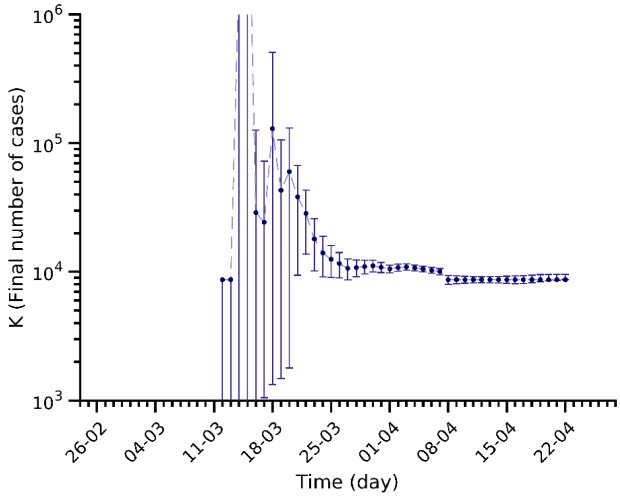


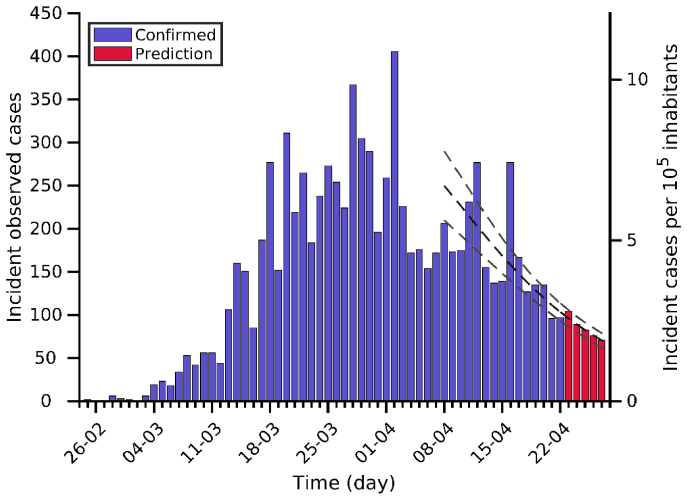
Toscana 22-04-2020. Population: 3.7M. Current cumulated incidence: 233/10^5

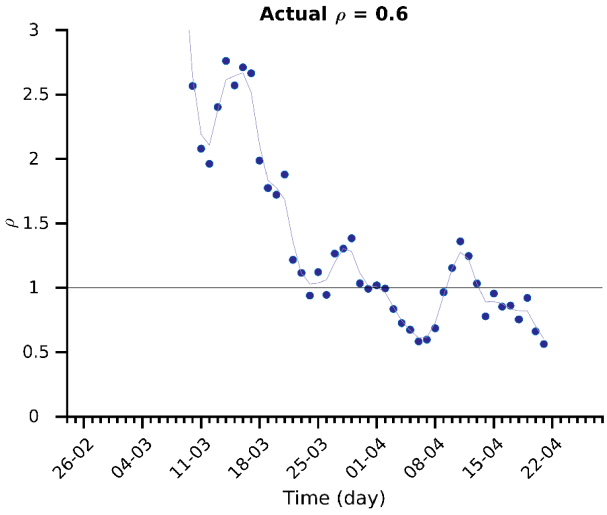


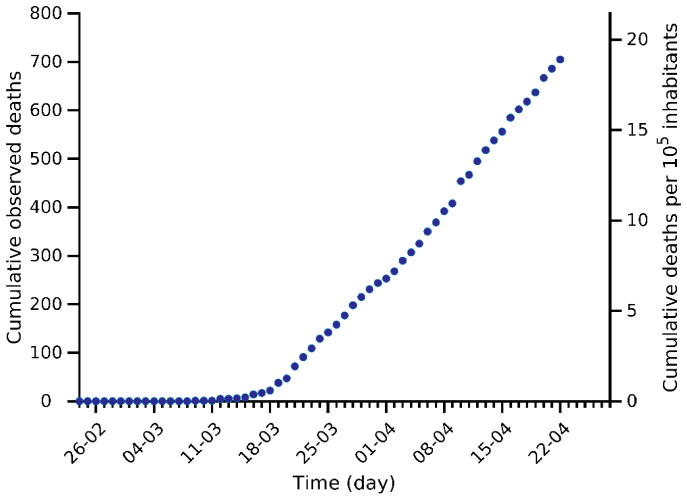


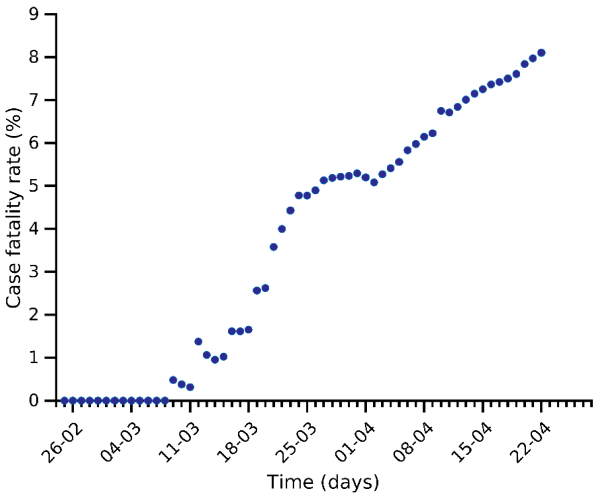




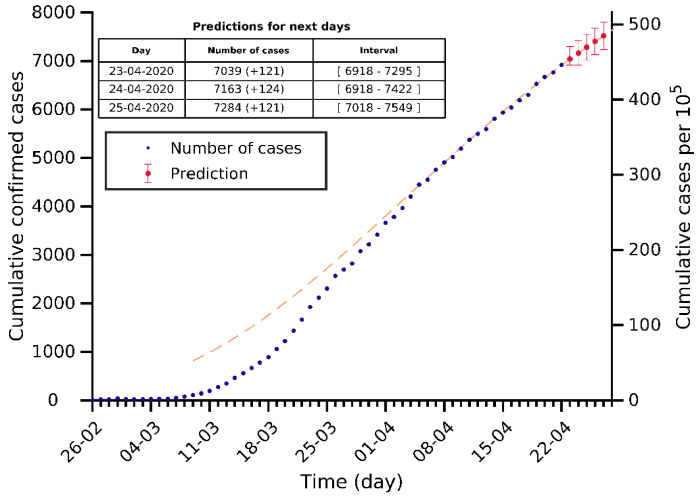


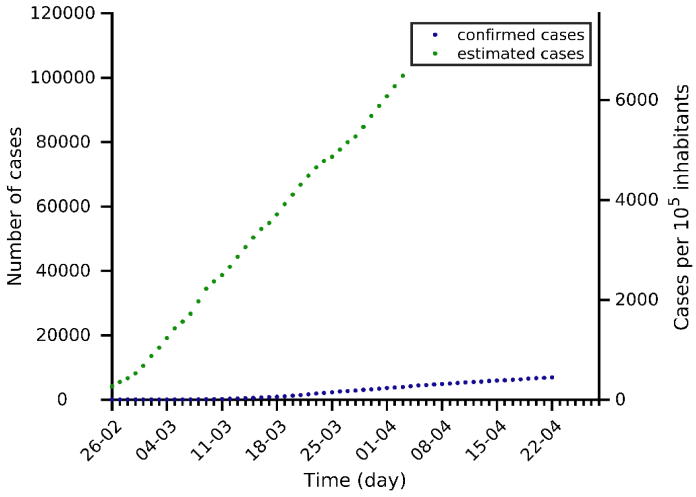


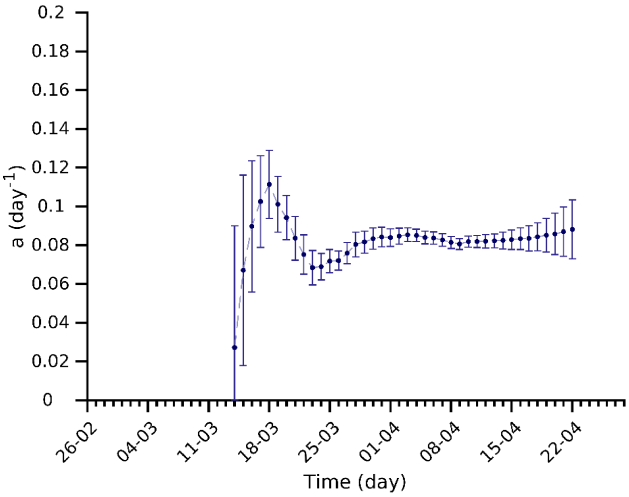


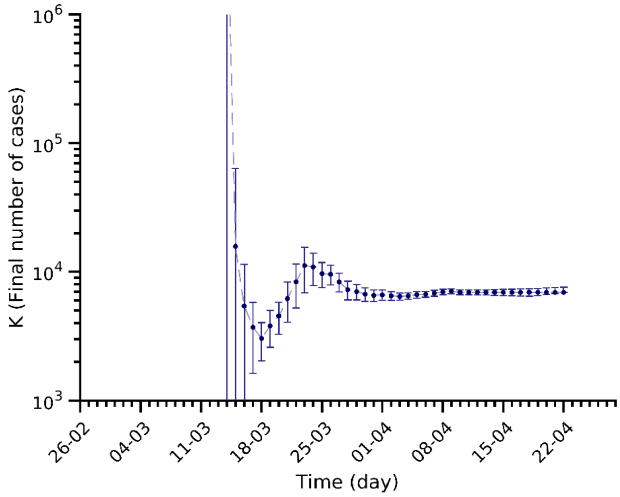


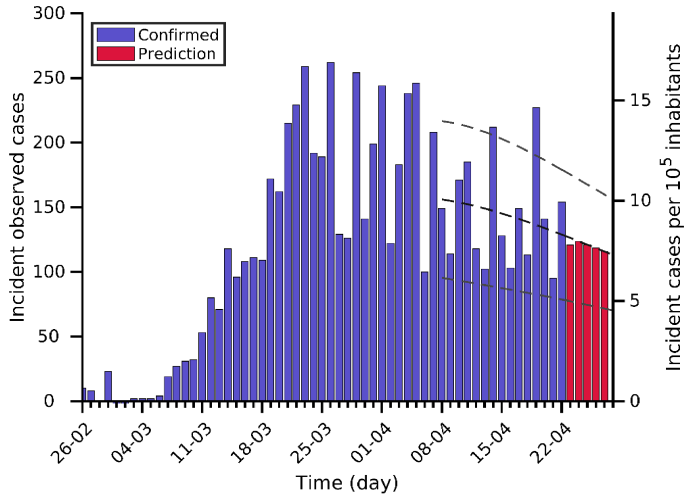
Liguria 22-04-2020. Population: 1.6M. Current cumulated incidence: 446/10^5

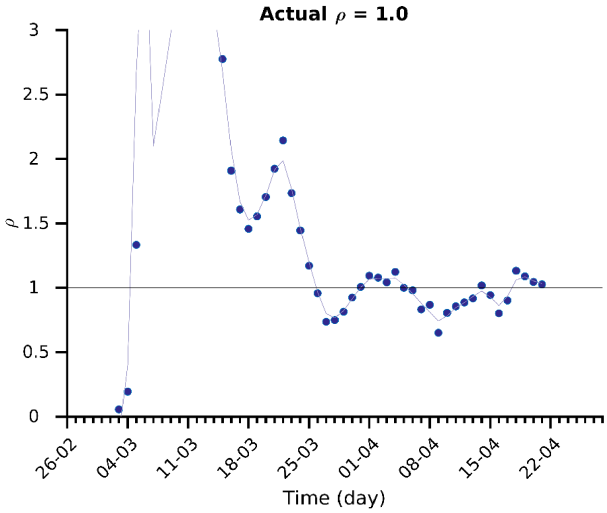


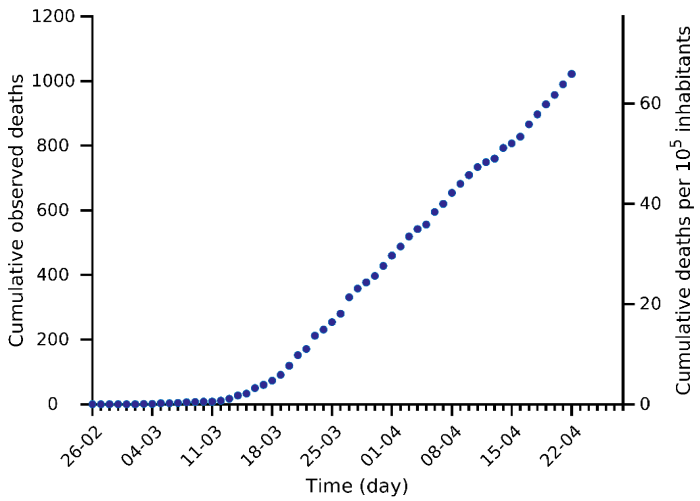


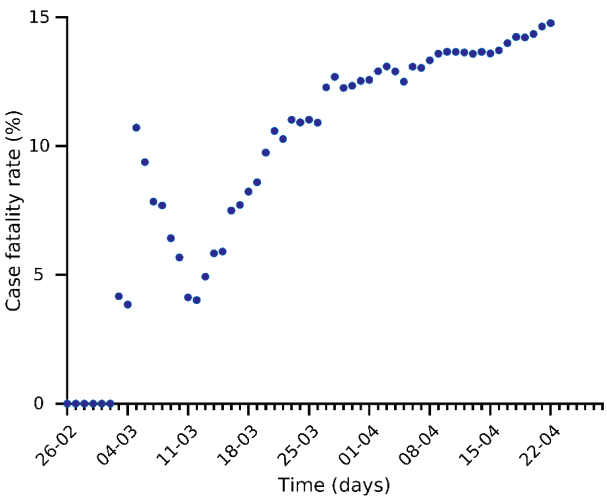




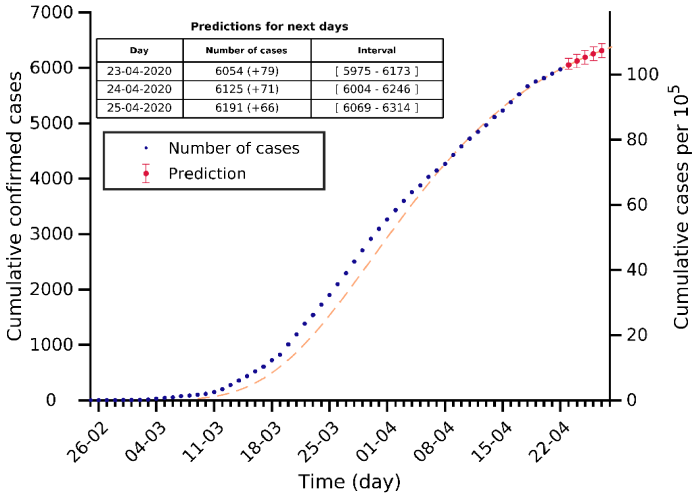


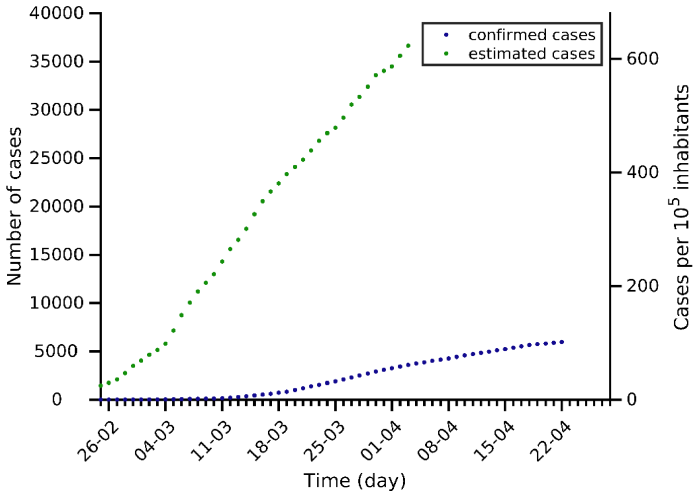


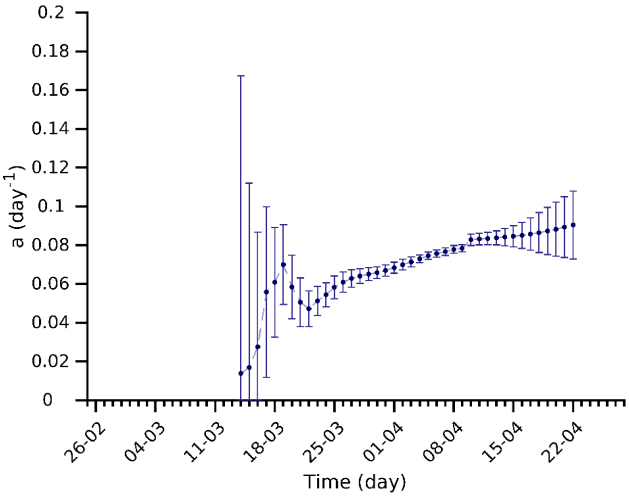


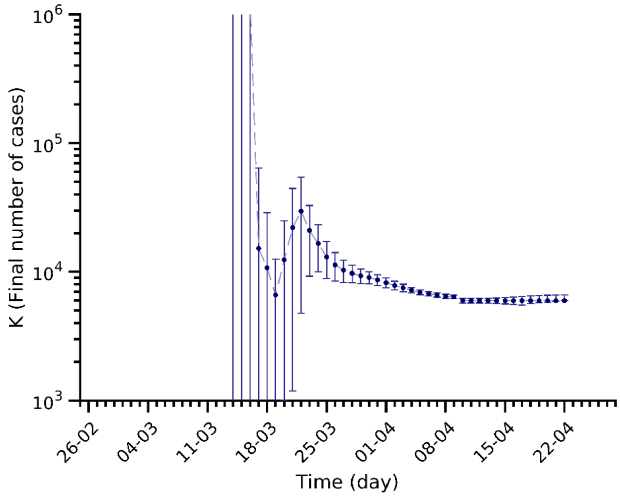


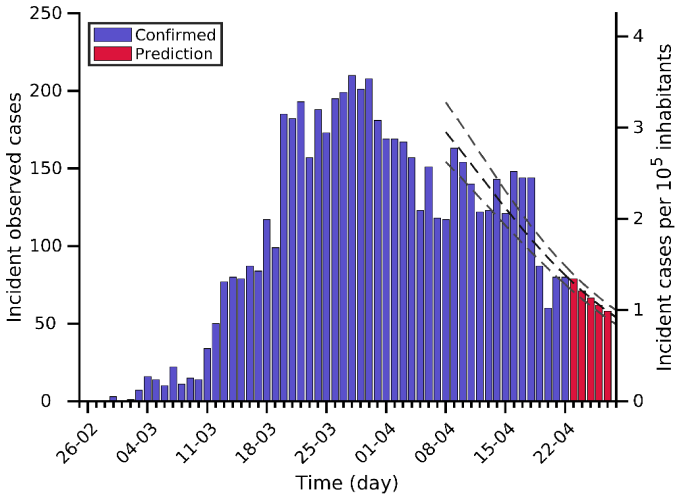
Lazio 22-04-2020. Population: 5.9M. Current cumulated incidence: 102/10⁵

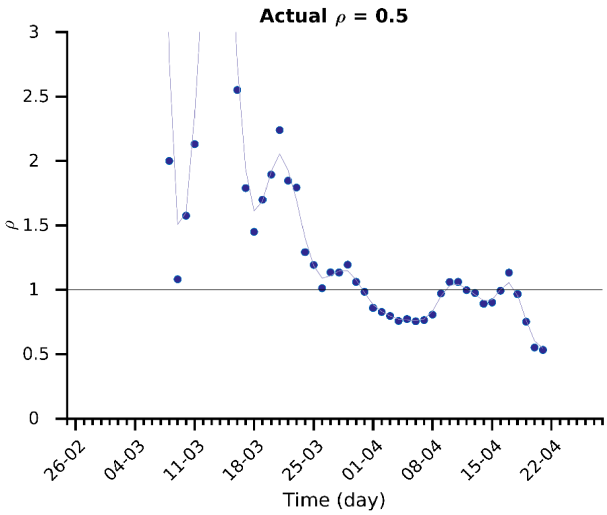


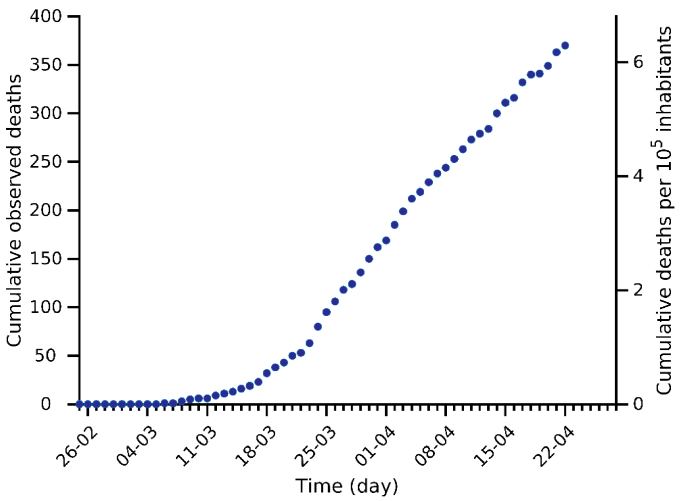


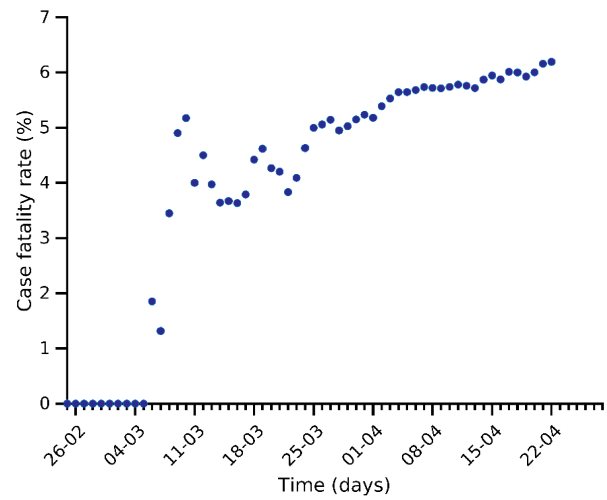




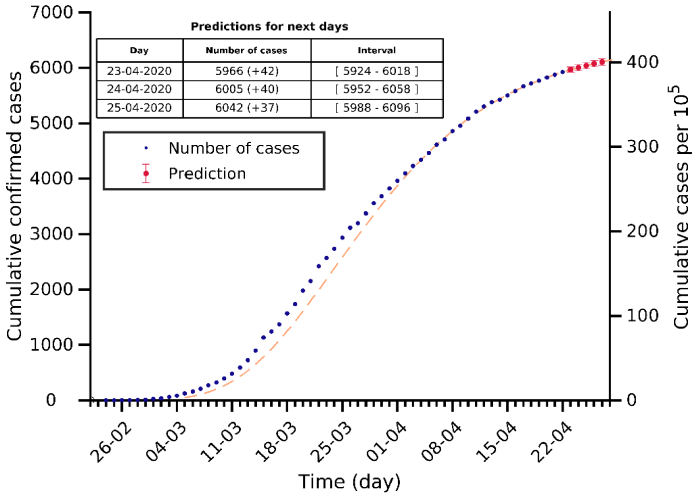


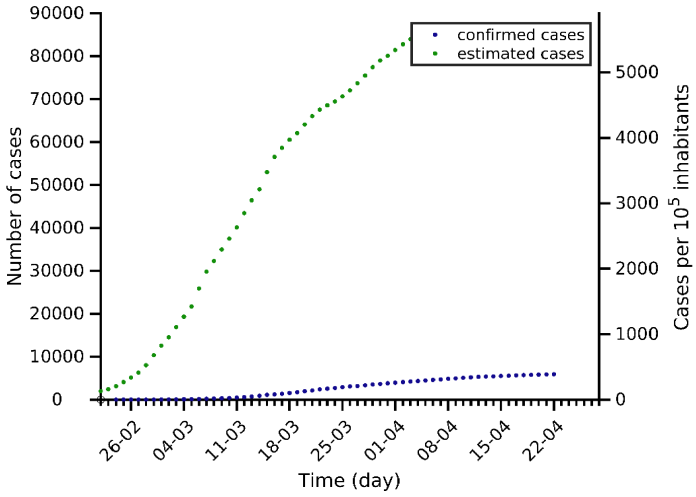


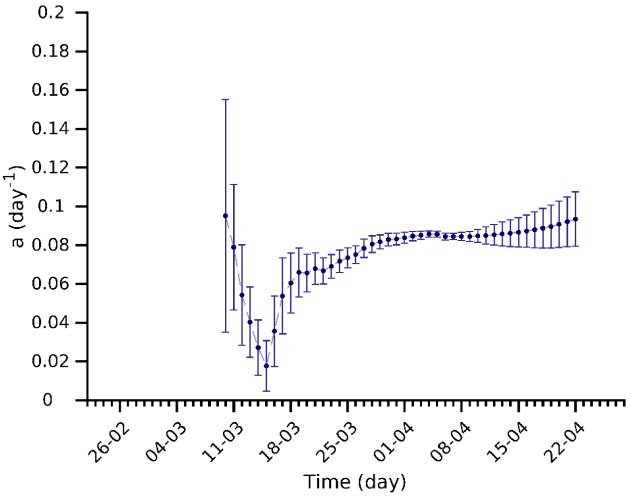


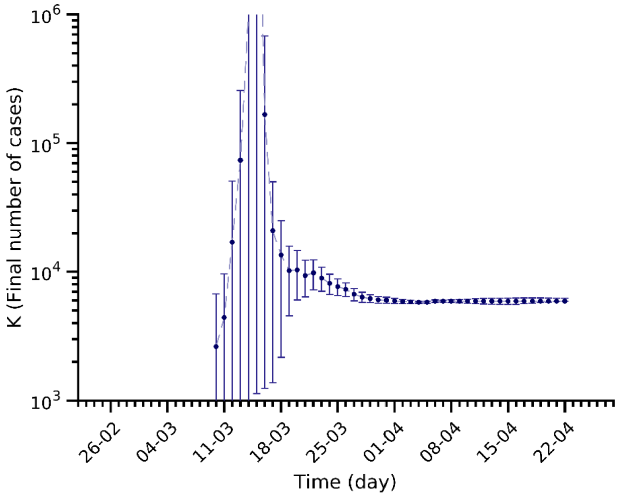


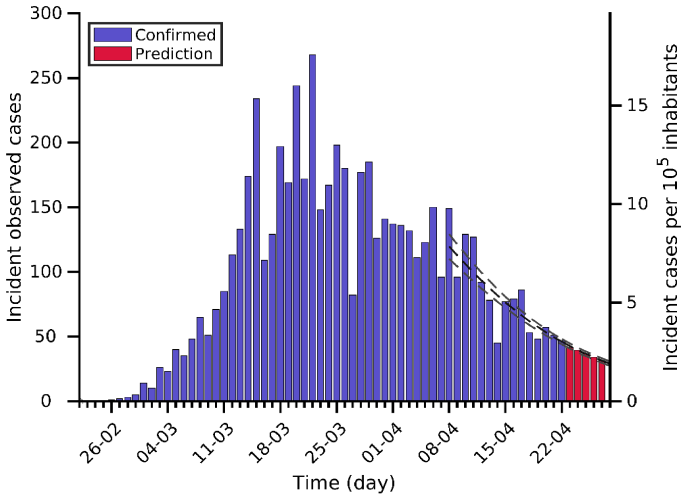
Marche 22-04-2020. Population: 1.5M. Current cumulated incidence: 388/10⁵

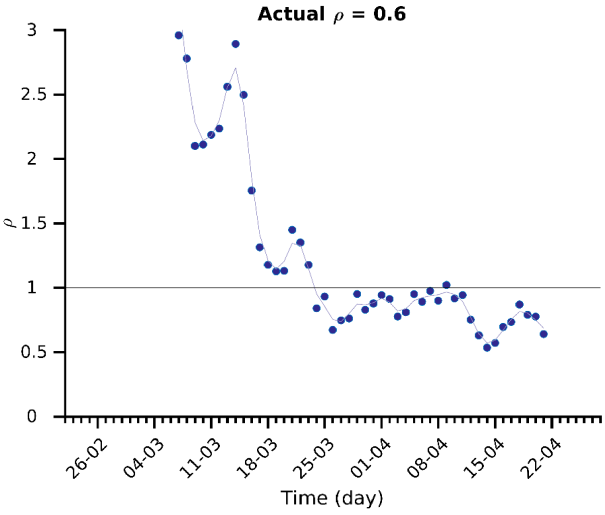


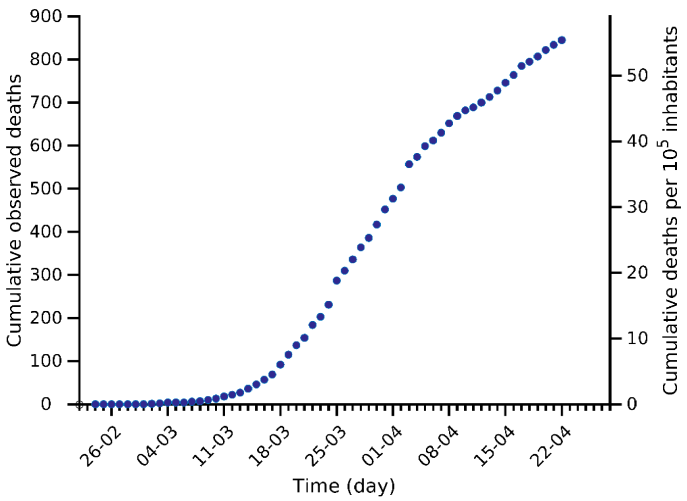


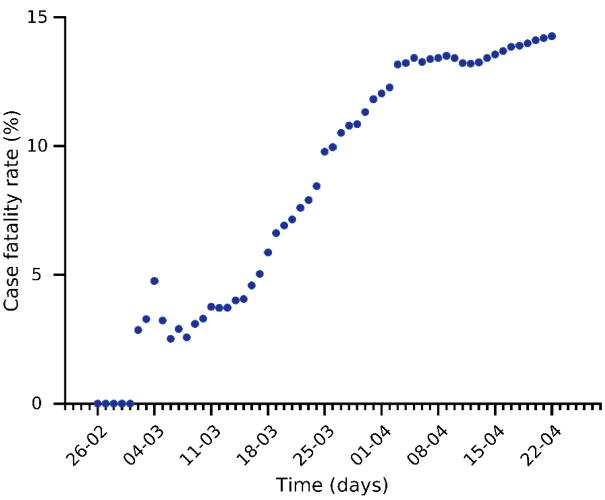




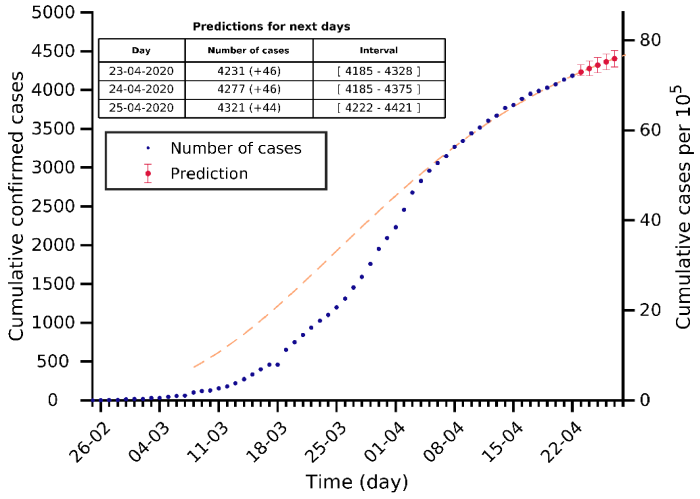


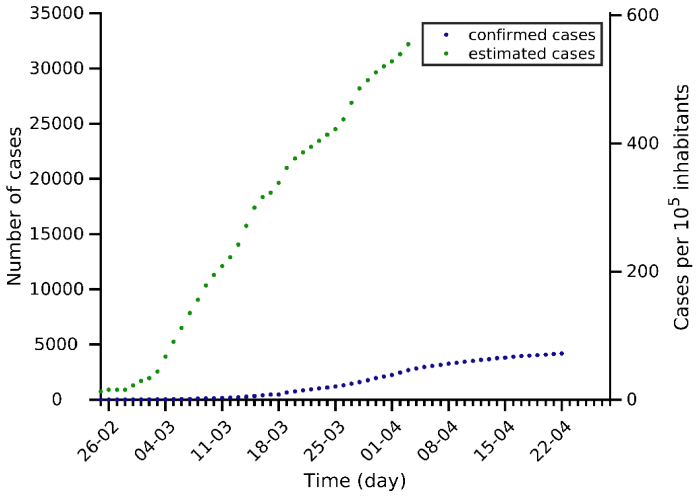


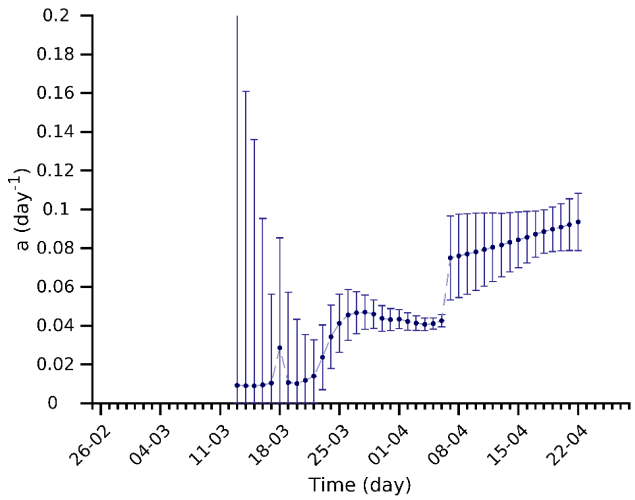


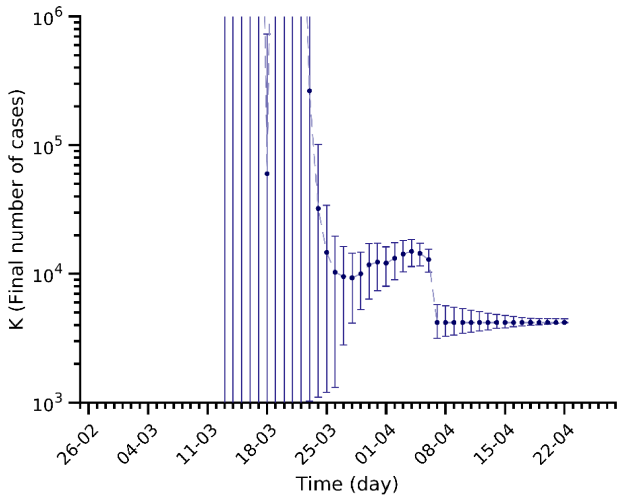


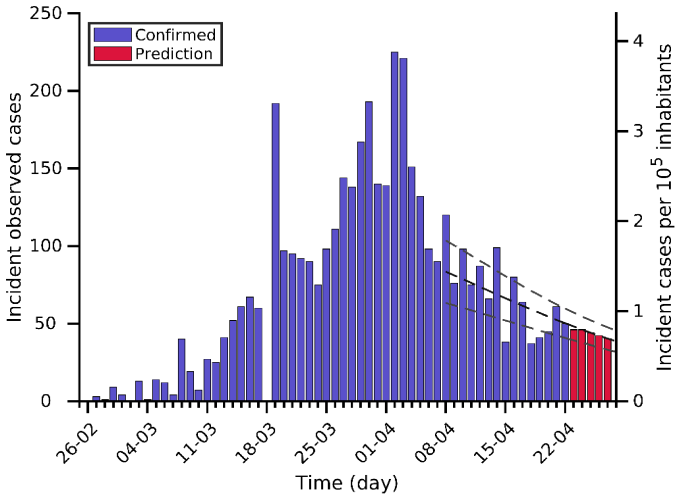
Campania 22-04-2020. Population: 5.8M. Current cumulated incidence: 72/10^5

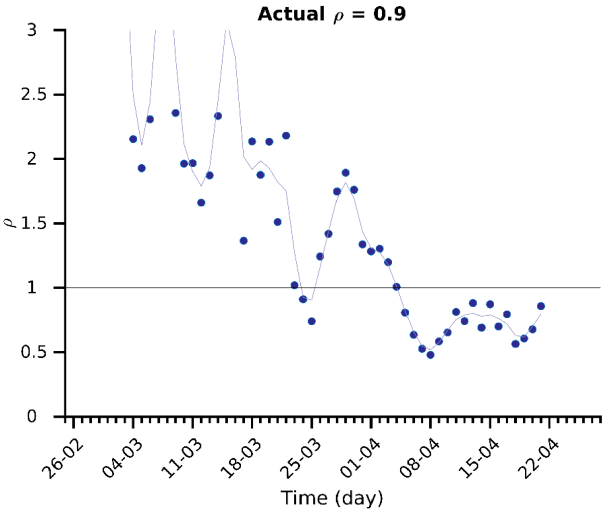


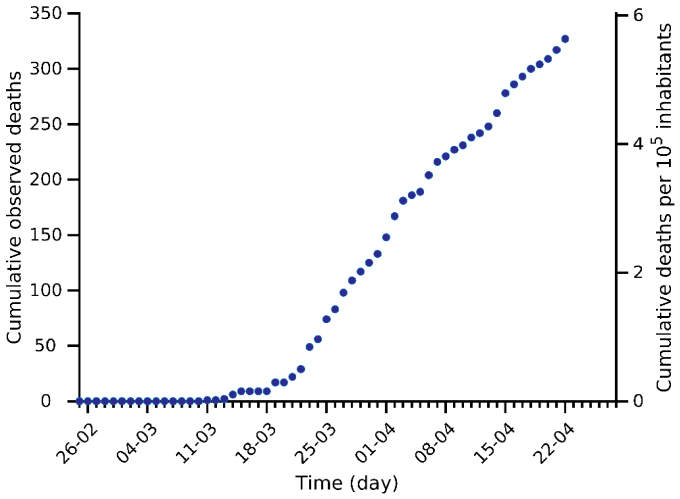


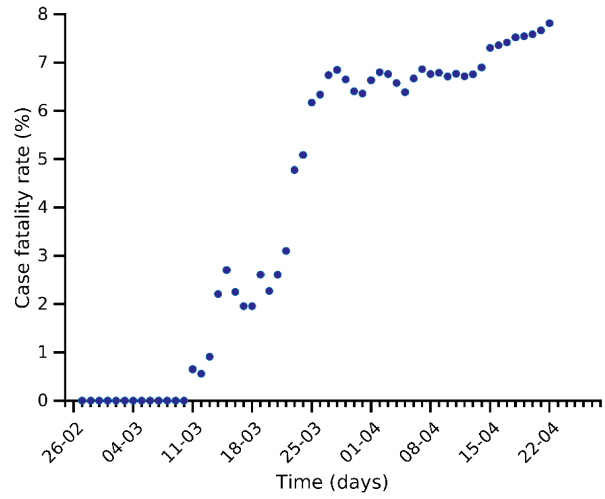




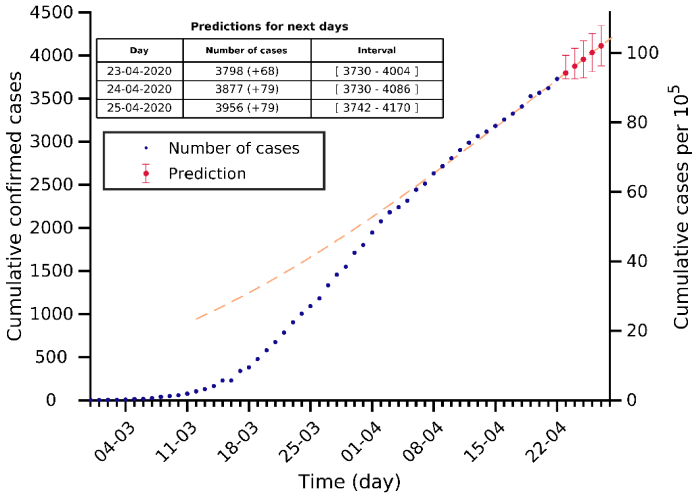


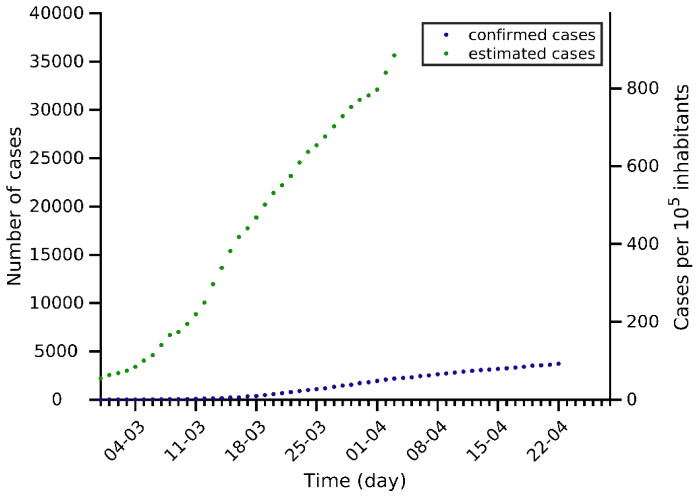


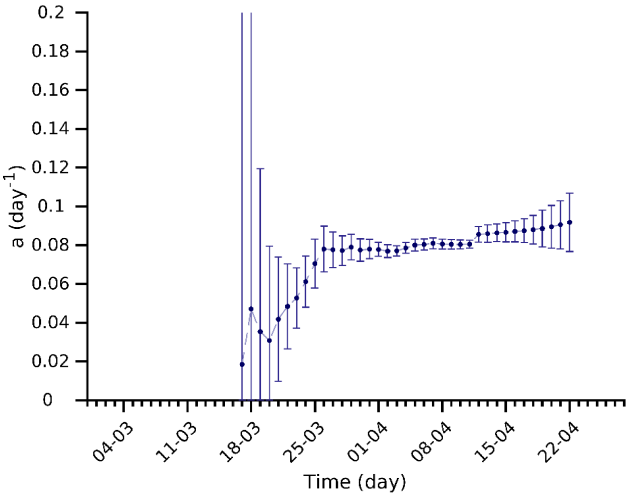


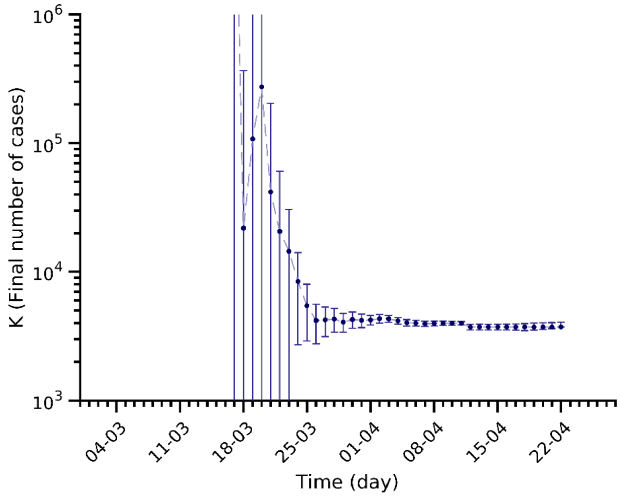


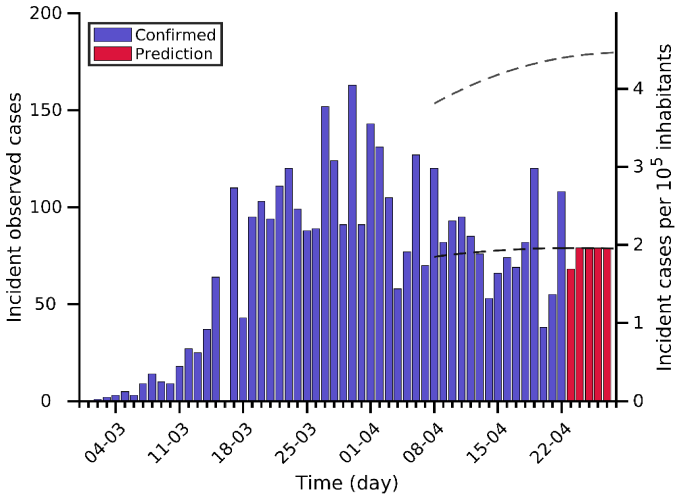
Puglia 22-04-2020. Population: 4.0M. Current cumulated incidence: 93/10⁵

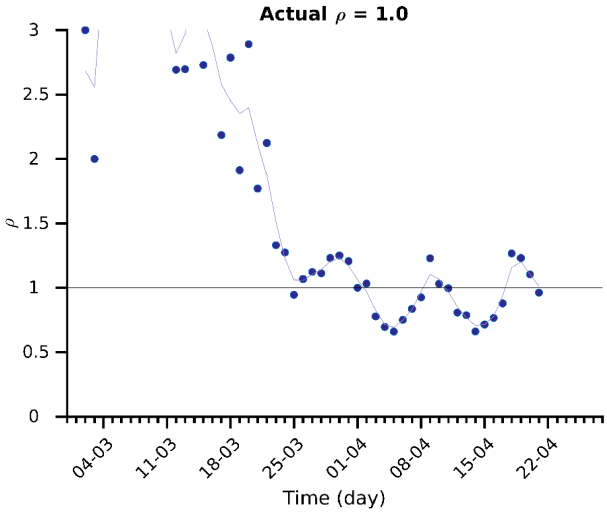


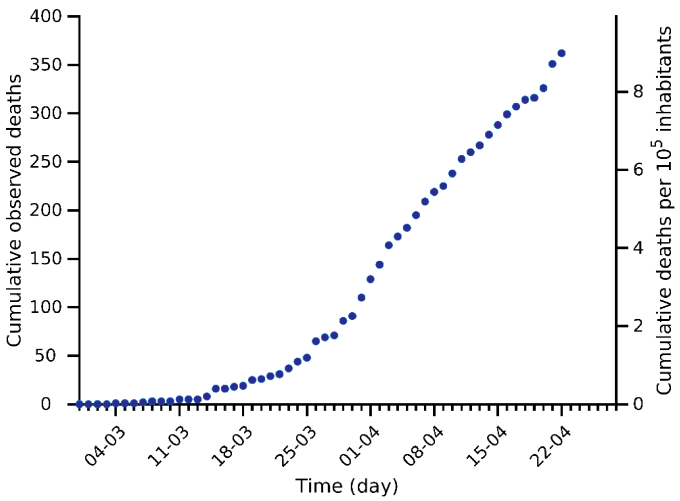


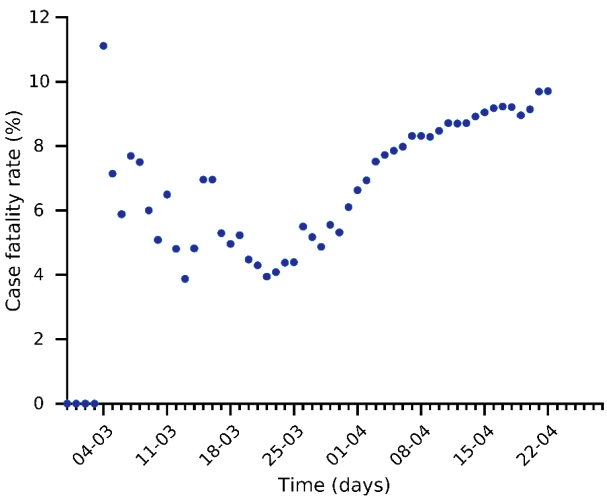




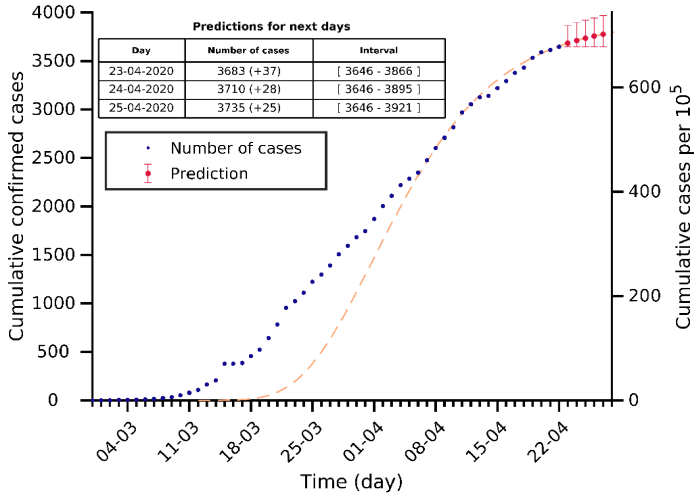


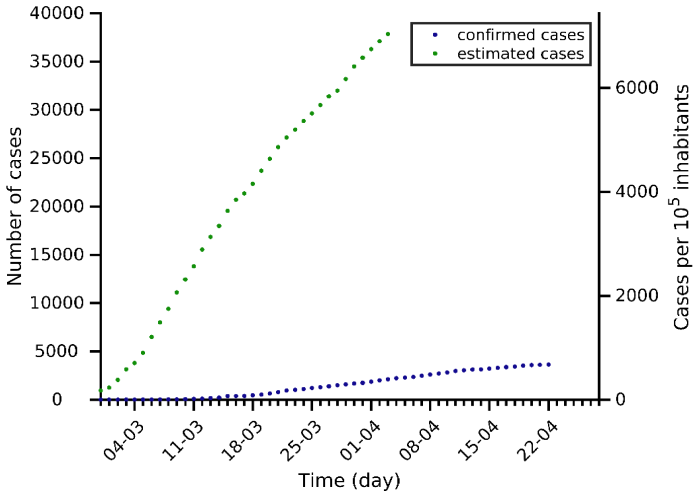


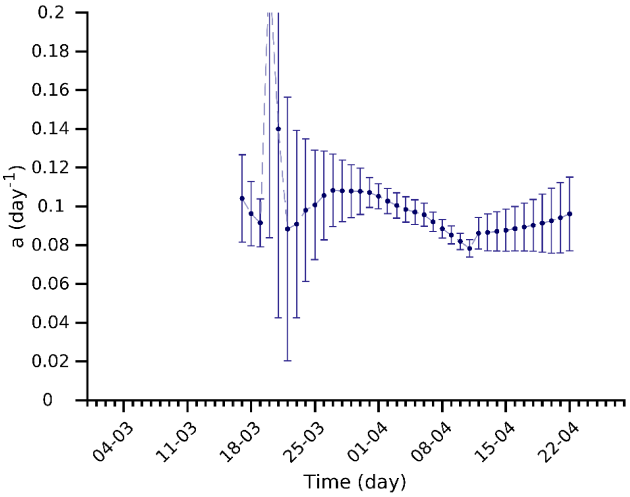


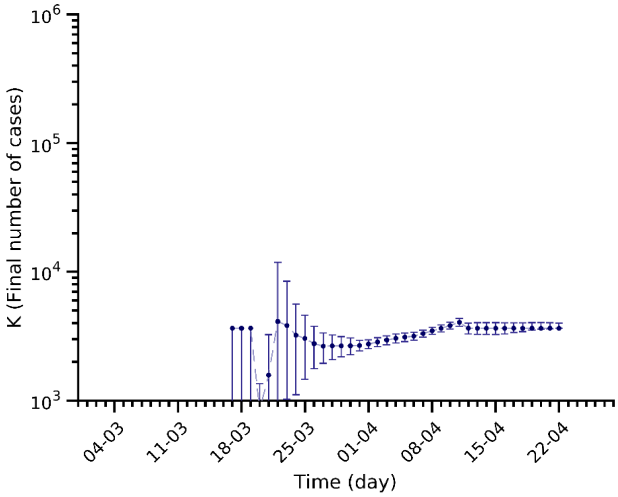


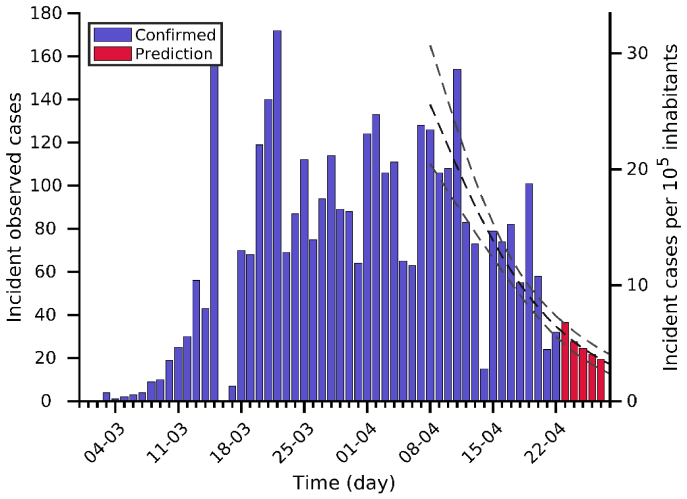
Trento 22-04-2020. Population: 0.5M. Current cumulated incidence: 678/10^5

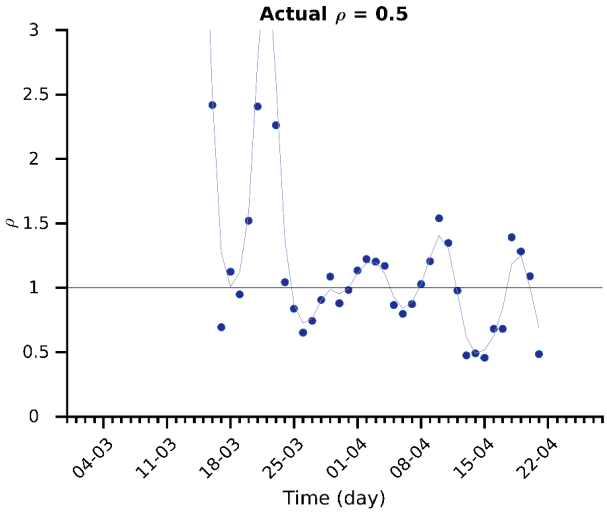


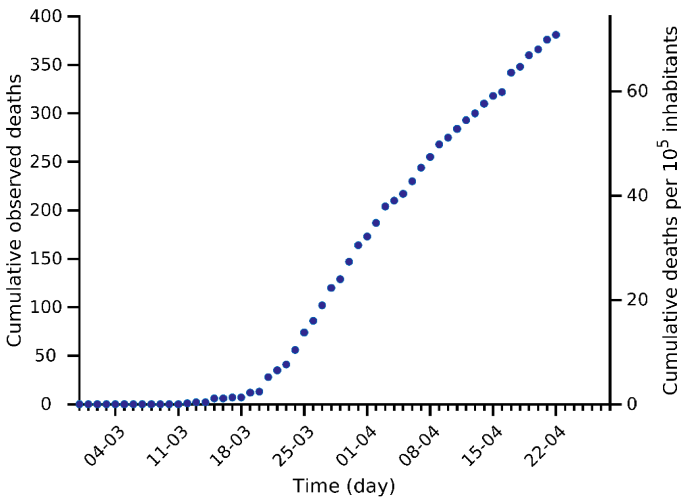


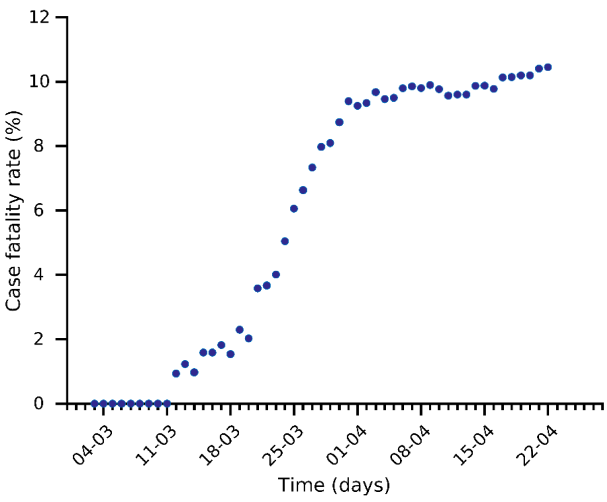




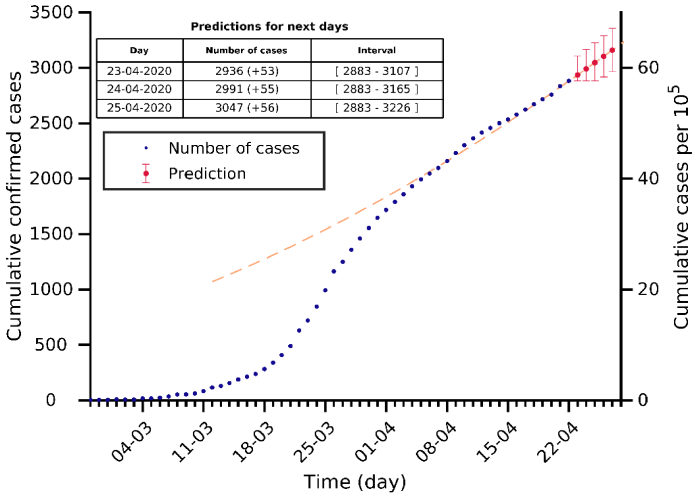


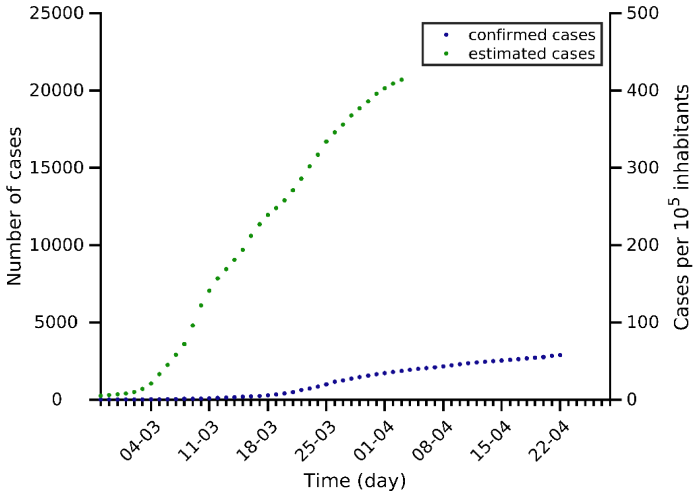


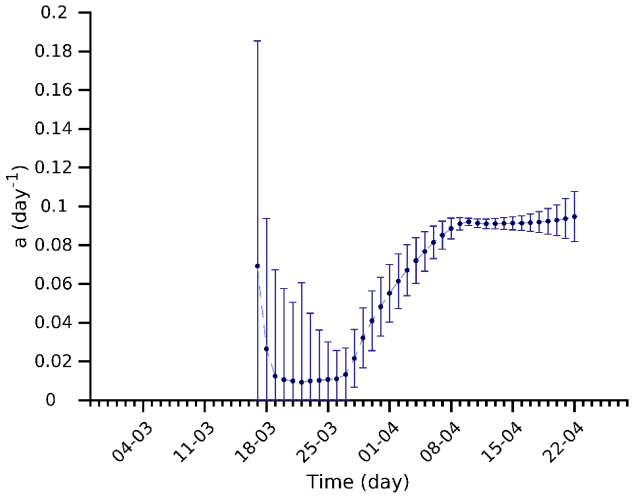


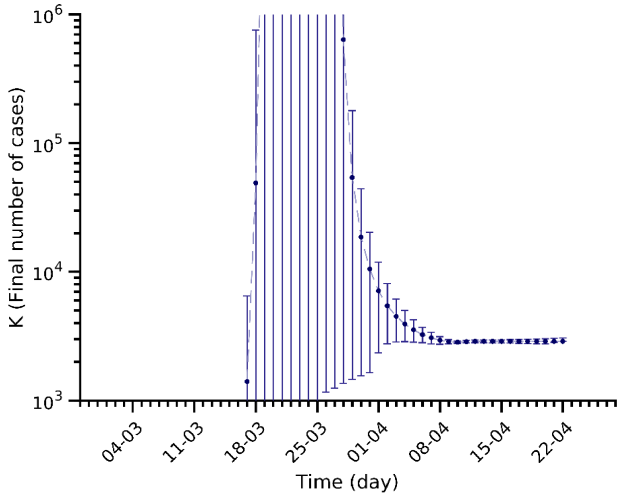


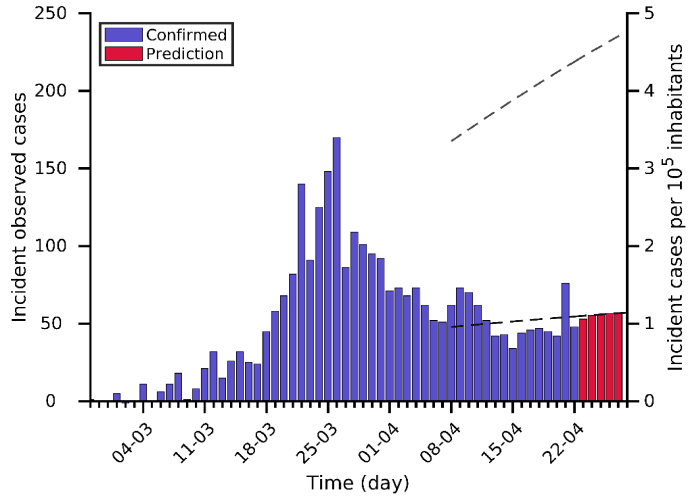
Sicilia 22-04-2020. Population: 5.0M. Current cumulated incidence: 58/10⁵

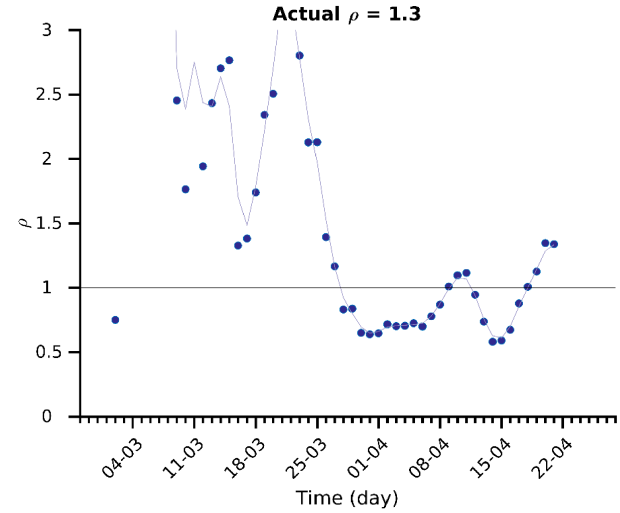


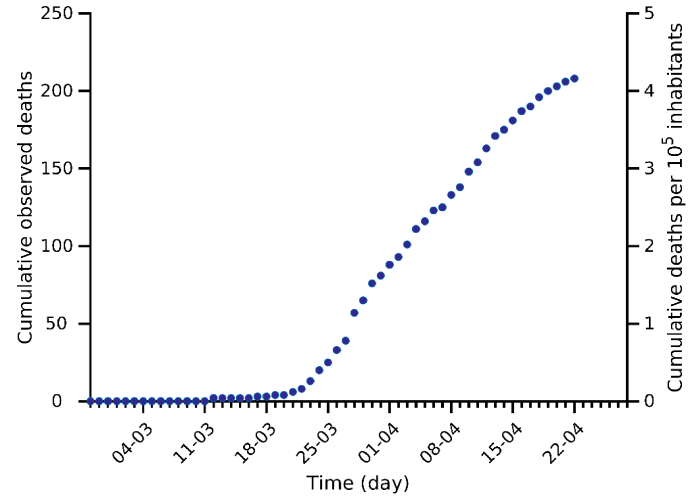


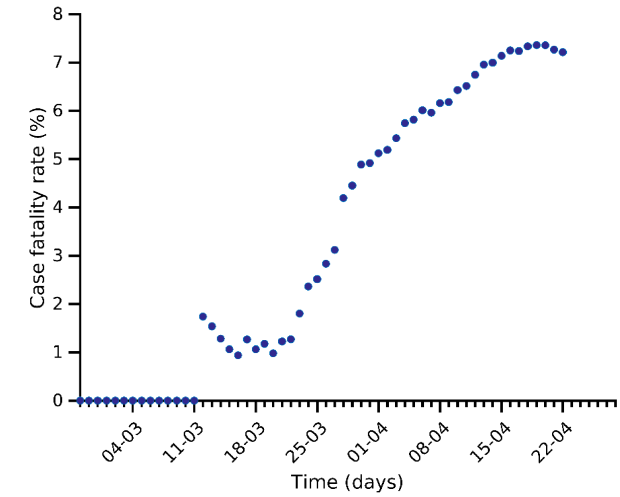




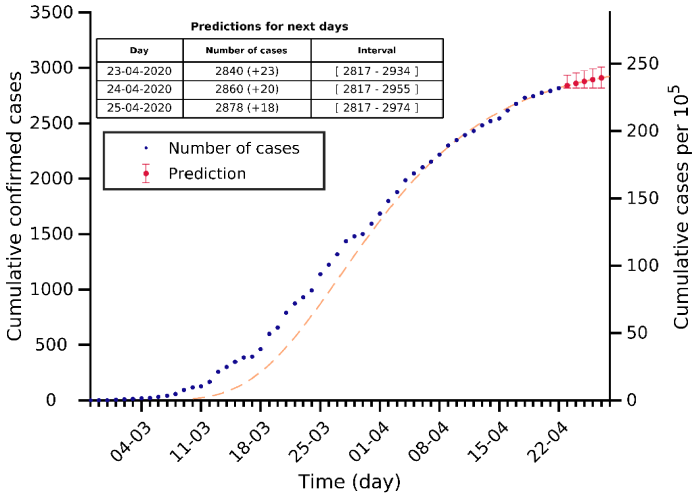


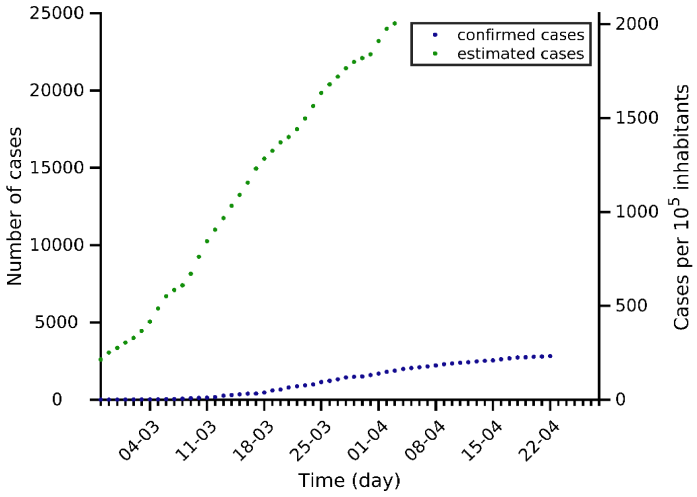


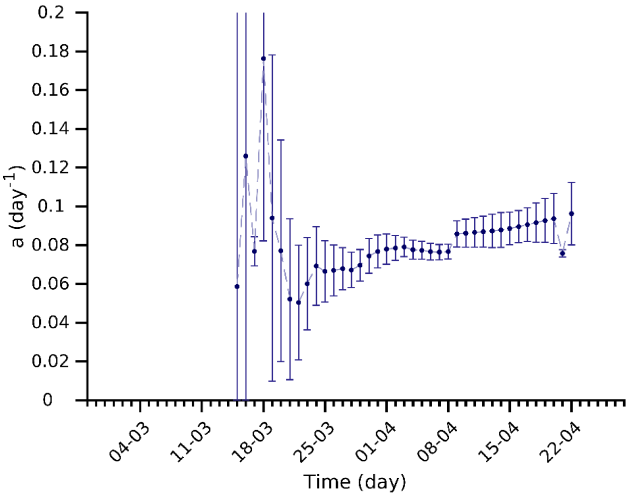


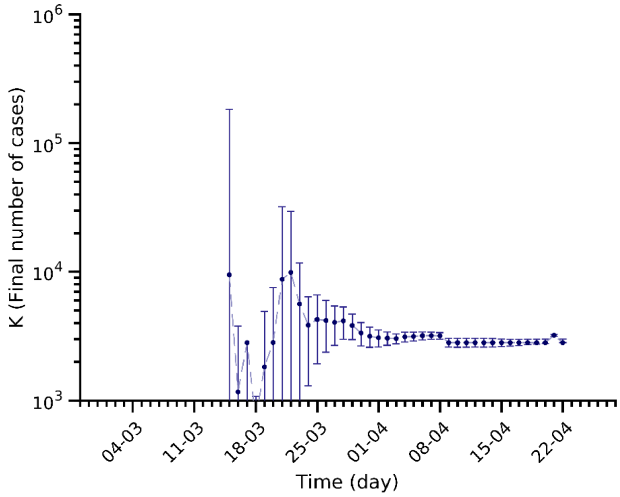


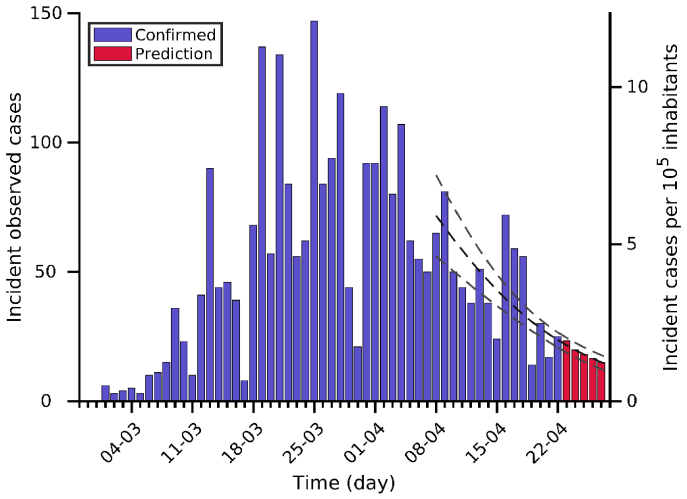
Friuli Venezia Giulia 22-04-2020. Population: 1.2M. Current cumulated incidence: 2

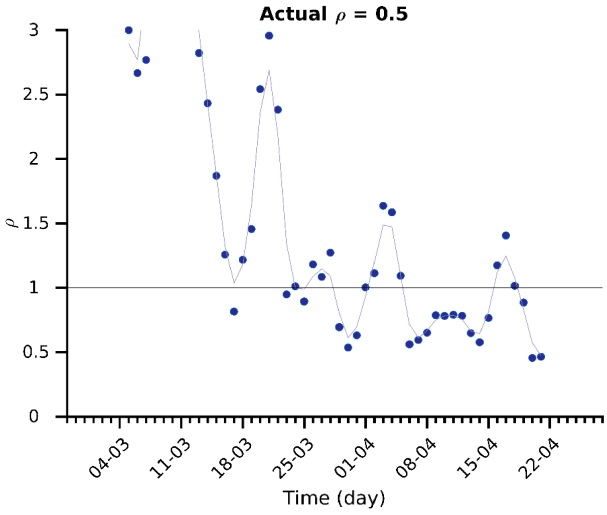


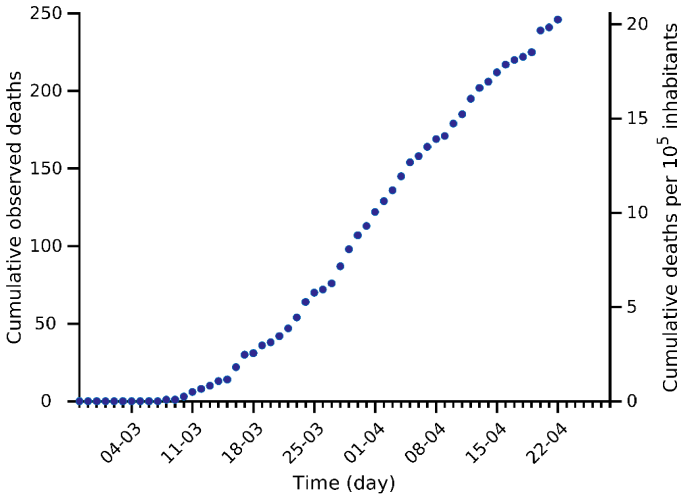


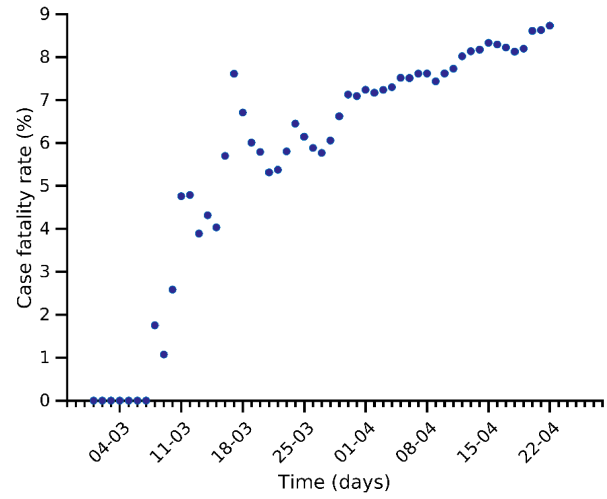




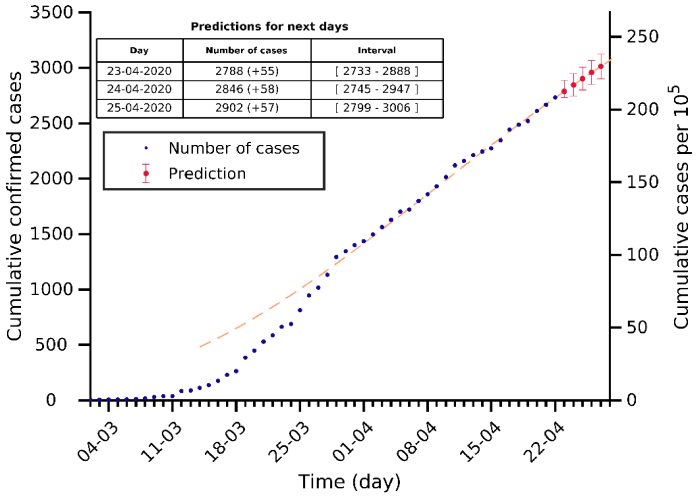


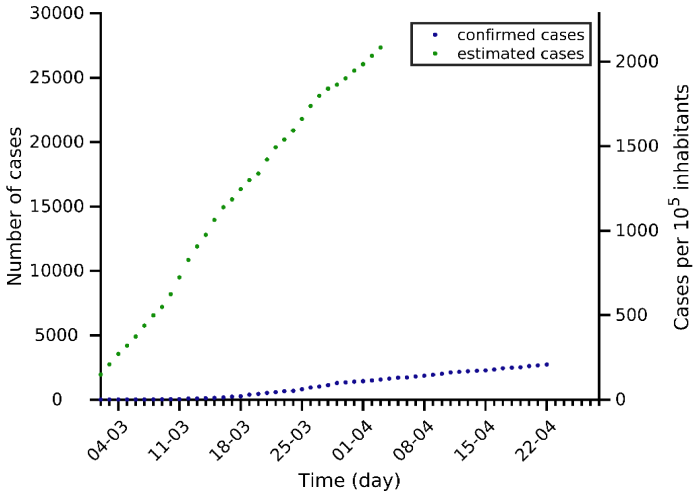


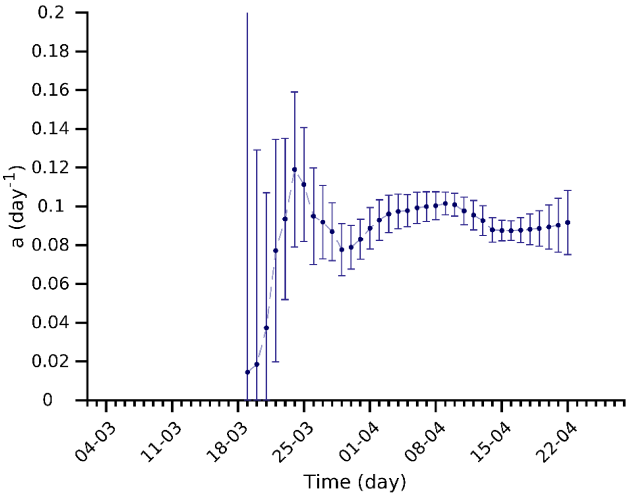


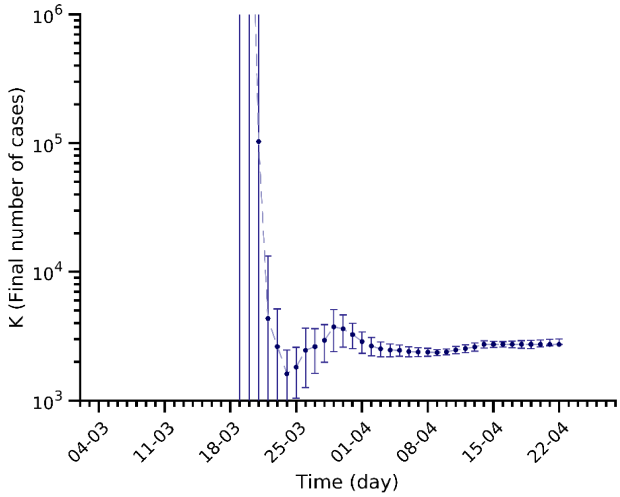


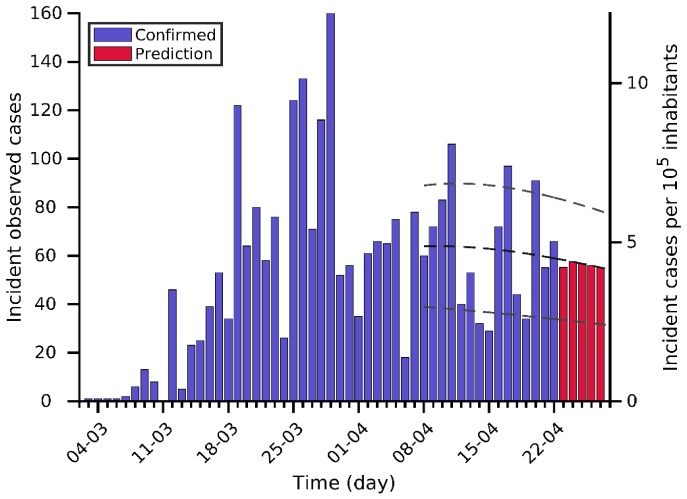
Abruzzo 22-04-2020. Population: 1.3M. Current cumulated incidence: 208/10^5

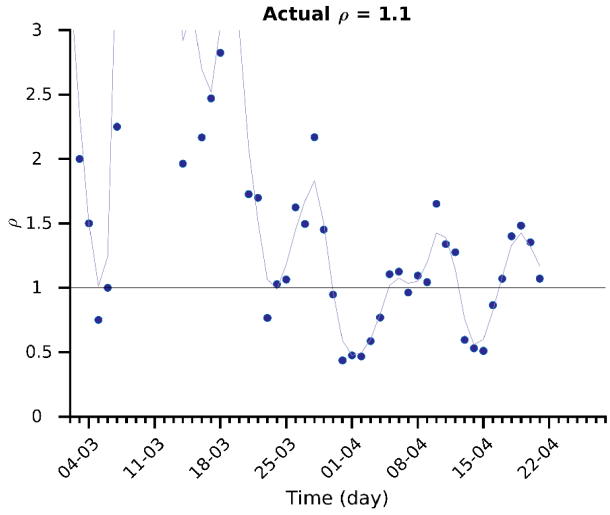


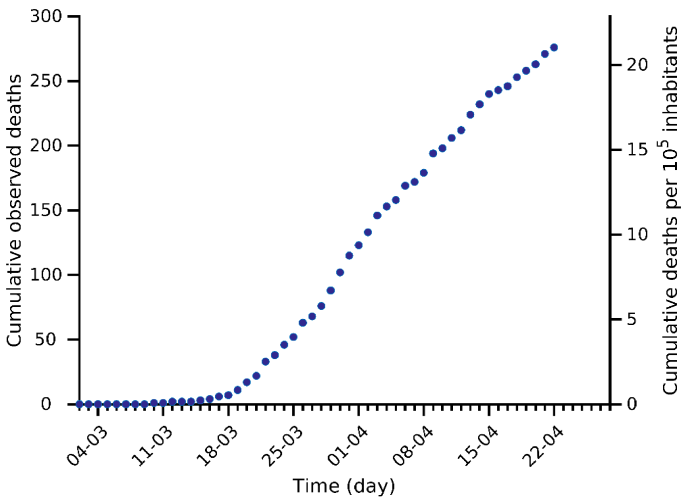


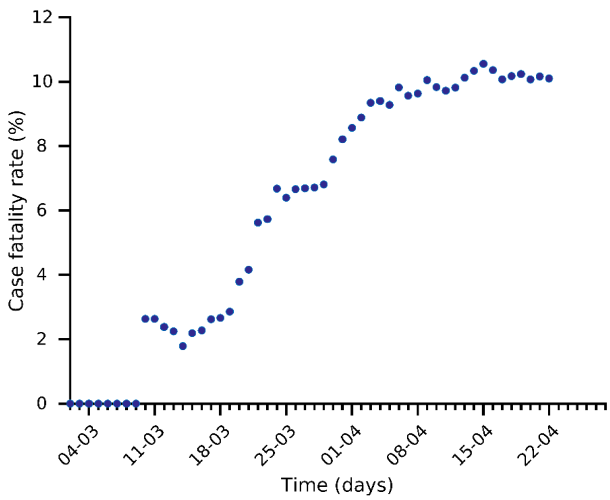




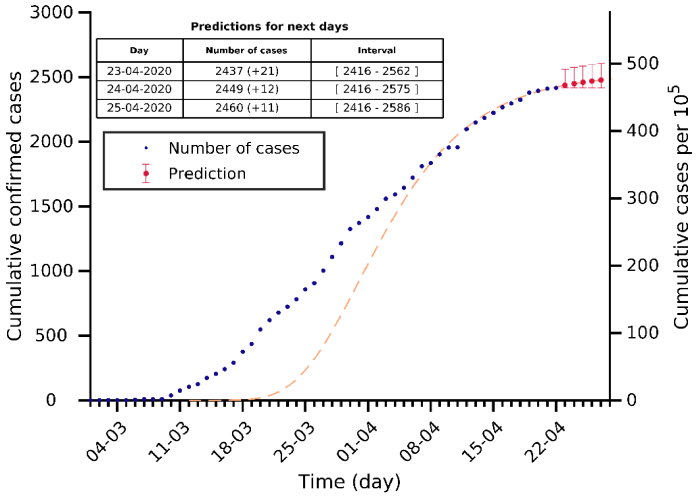


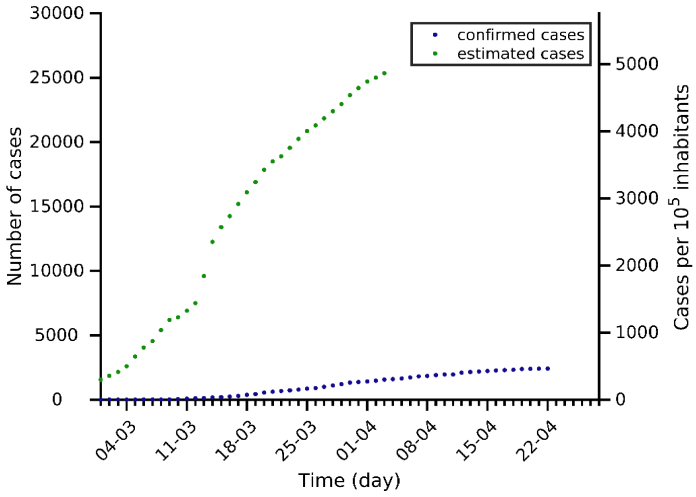


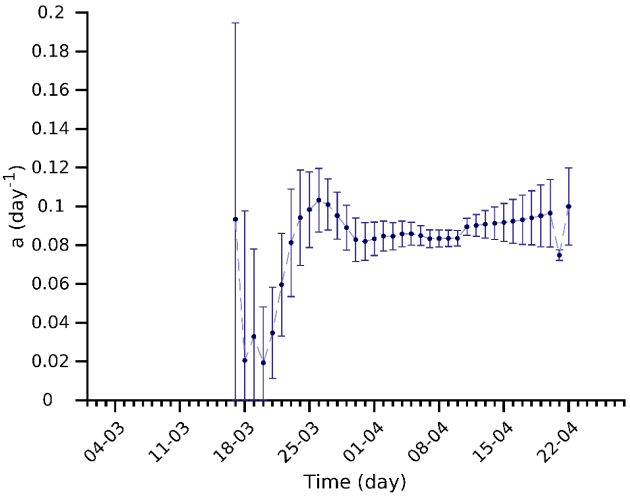


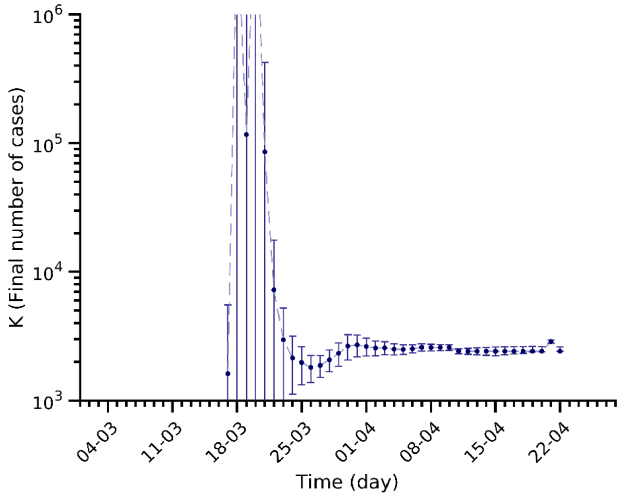


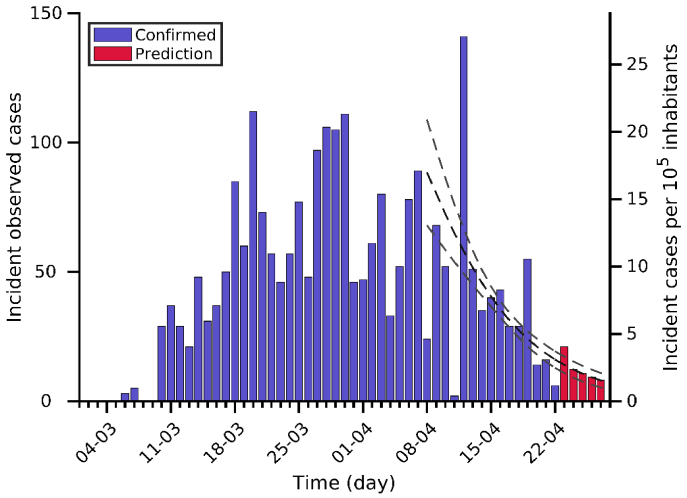
Bolzano 22-04-2020. Population: 0.5M. Current cumulated incidence: 464/10^5

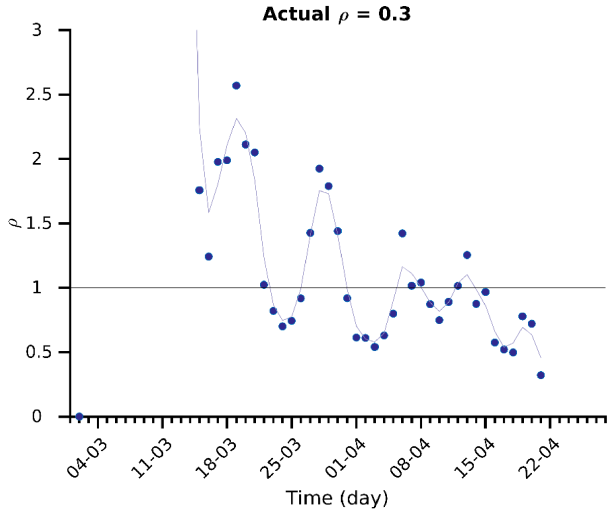


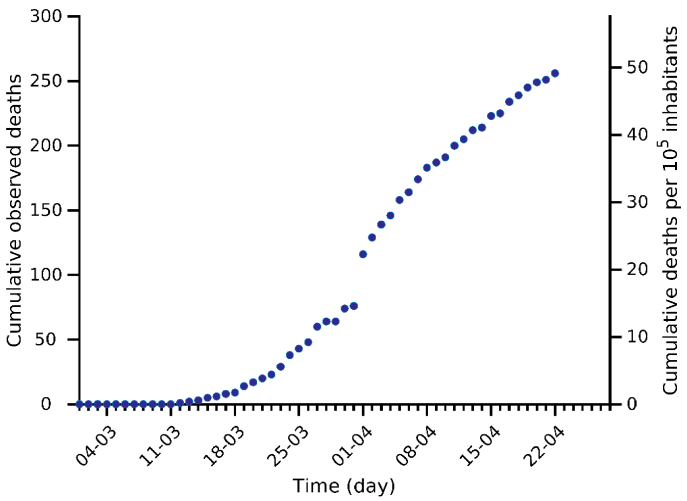


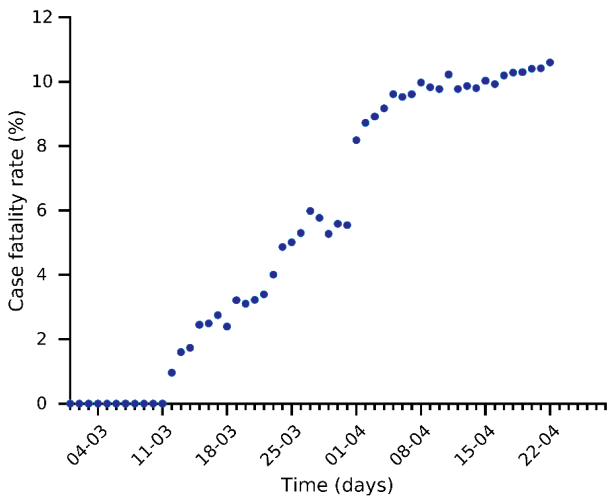




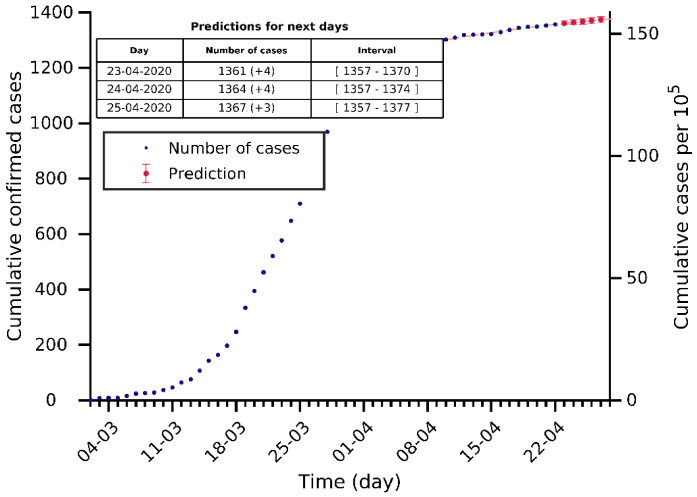


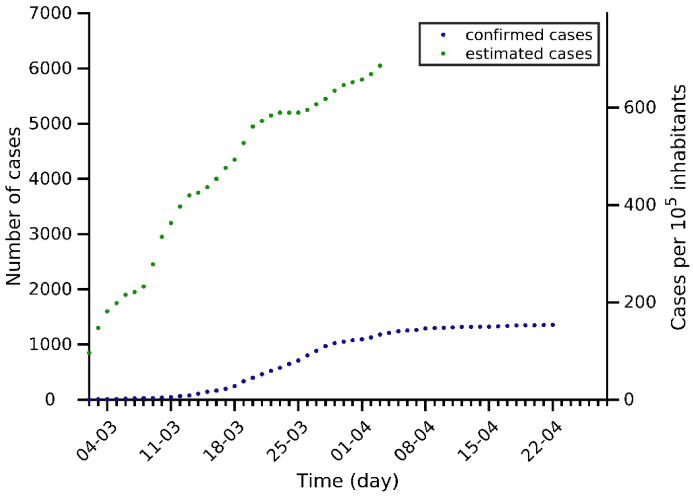


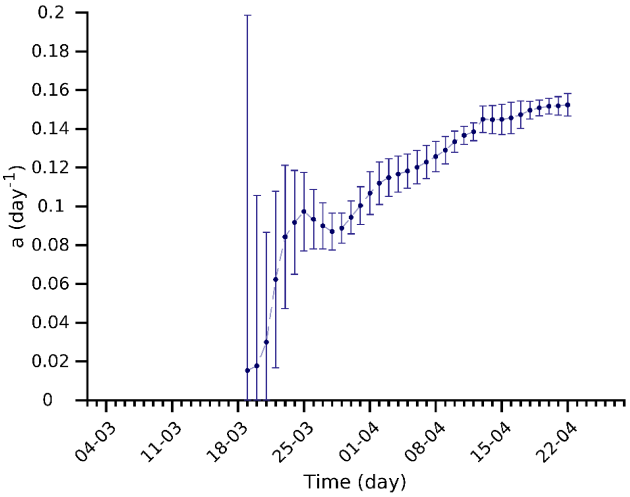


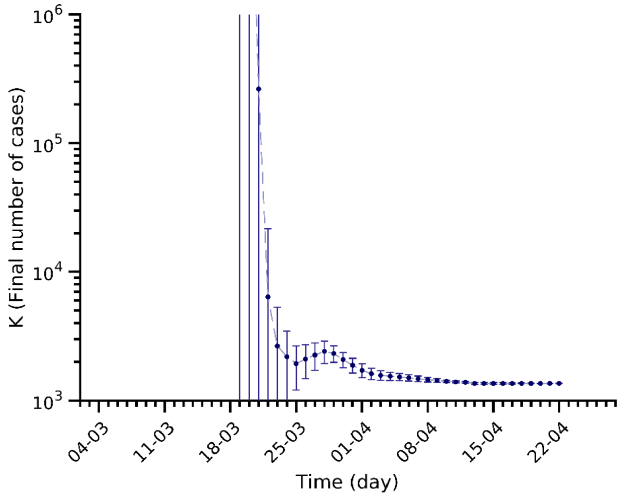


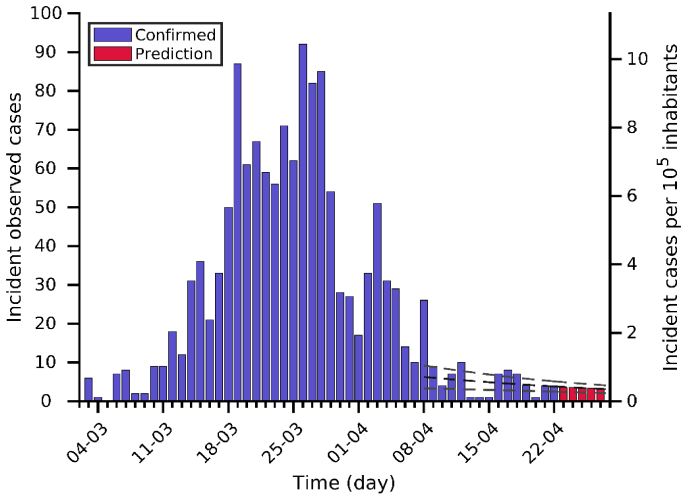
Umbria 22-04-2020. Population: 0.9M. Current cumulated incidence: 154/10⁵

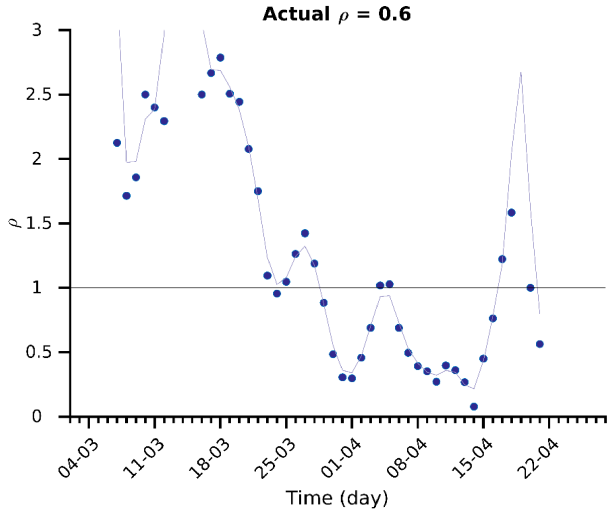


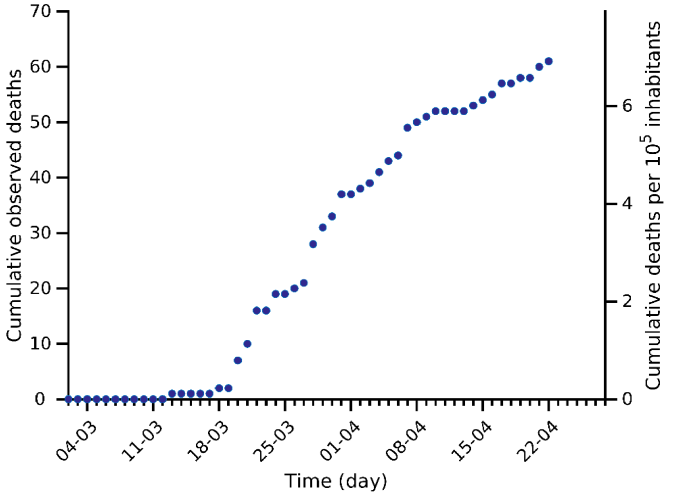


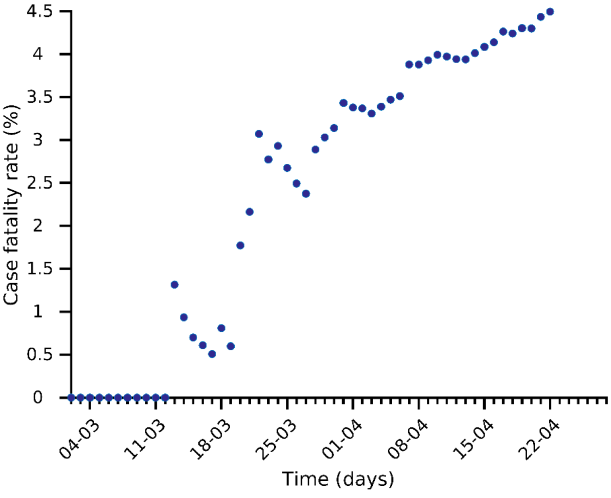




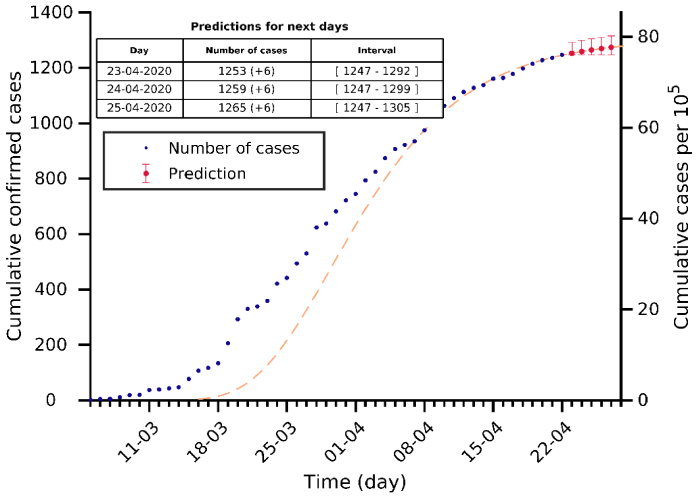


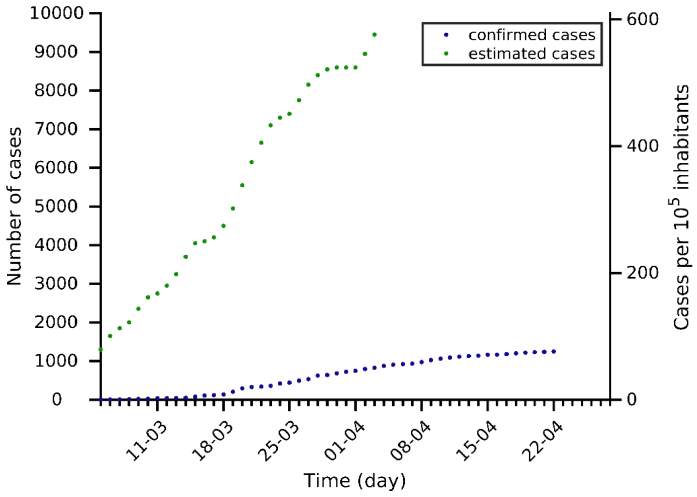


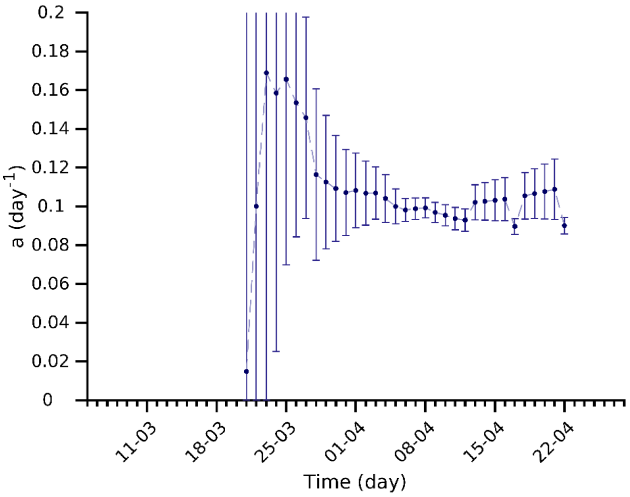


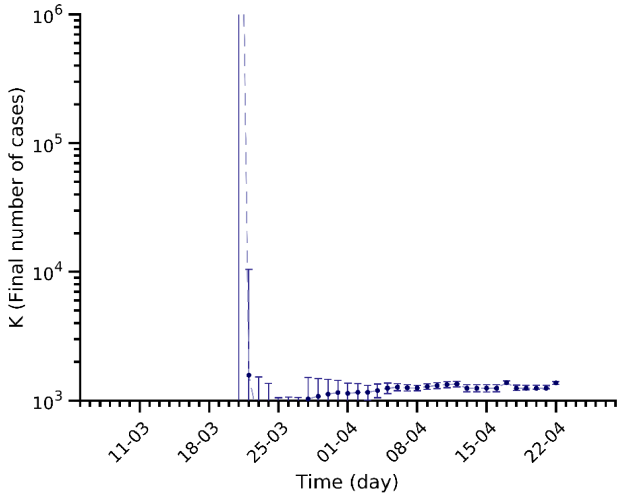


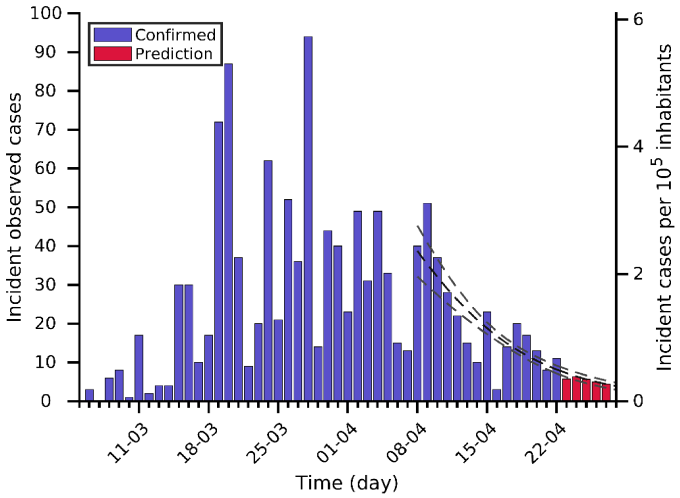
Sardegna 22-04-2020. Population: 1.6M. Current cumulated incidence: 76/10⁵

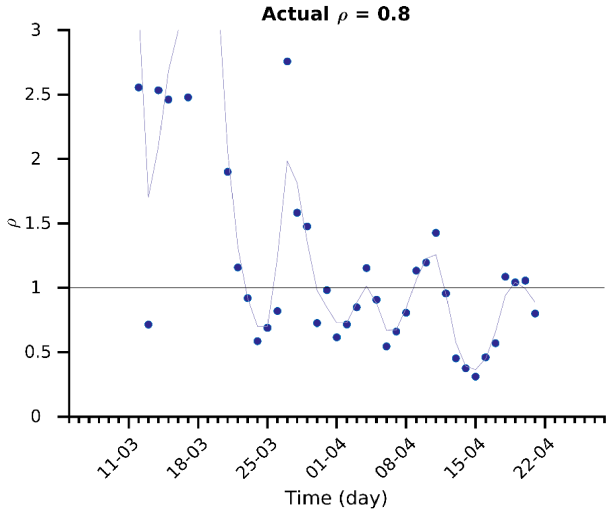


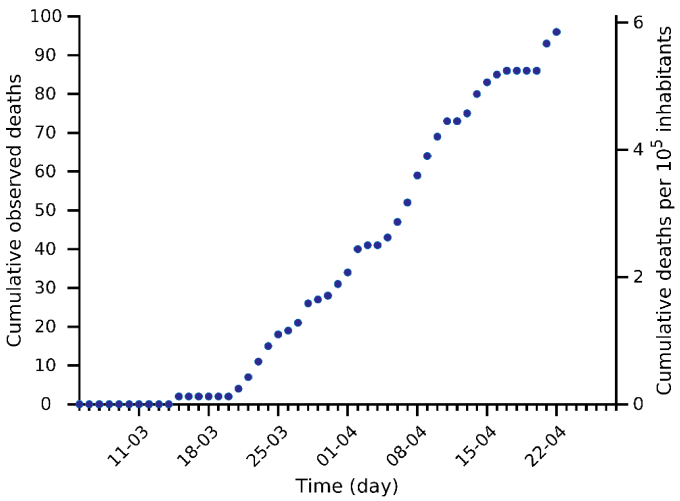


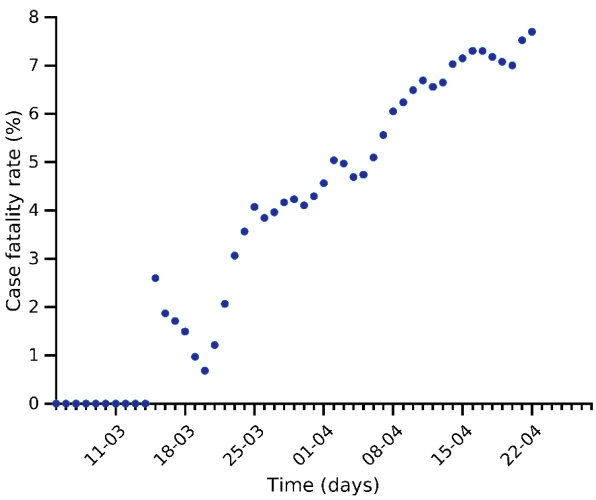




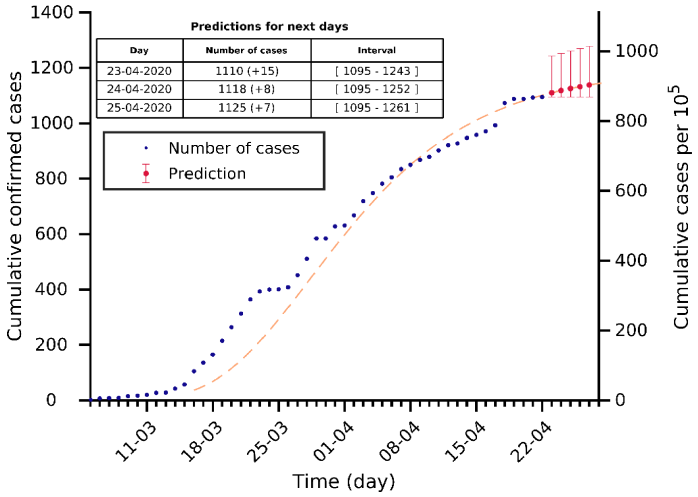


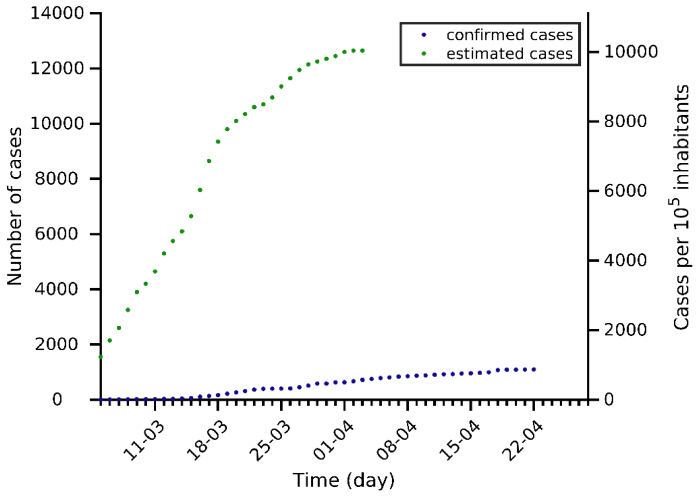


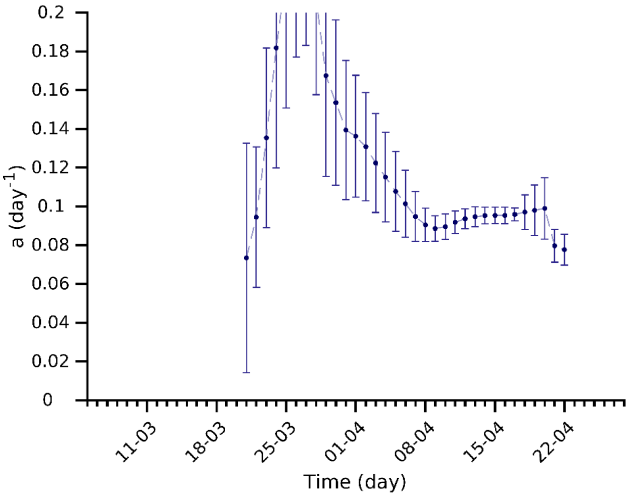


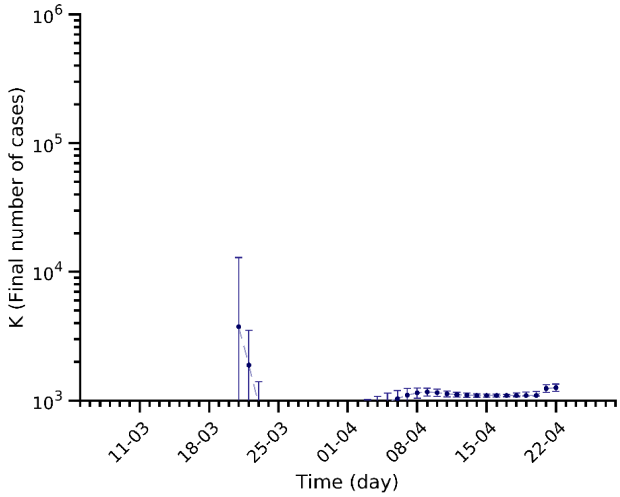


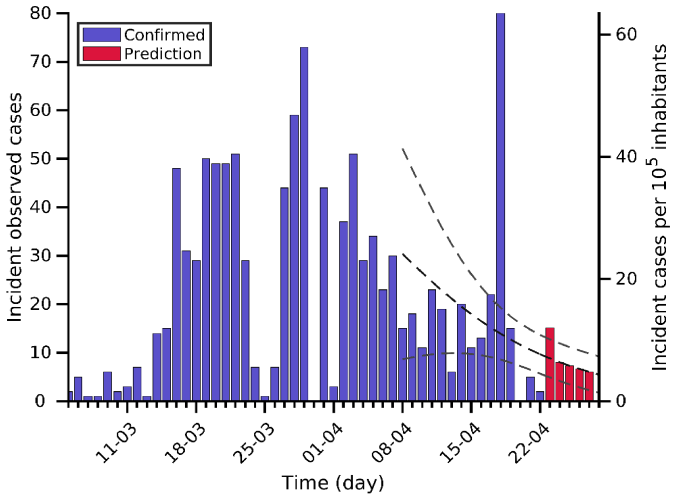
Valle dAosta 22-04-2020. Population: 0.1M. Current cumulated incidence: 869/10^5

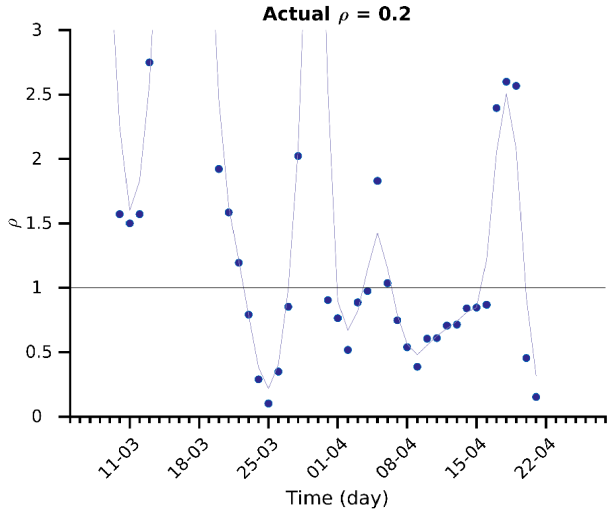


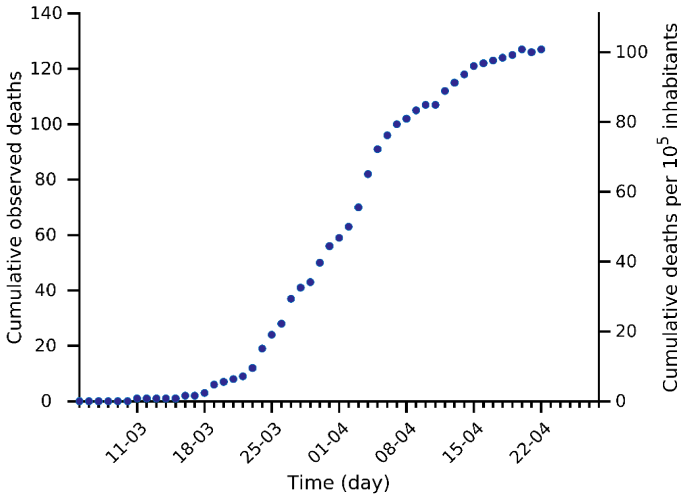


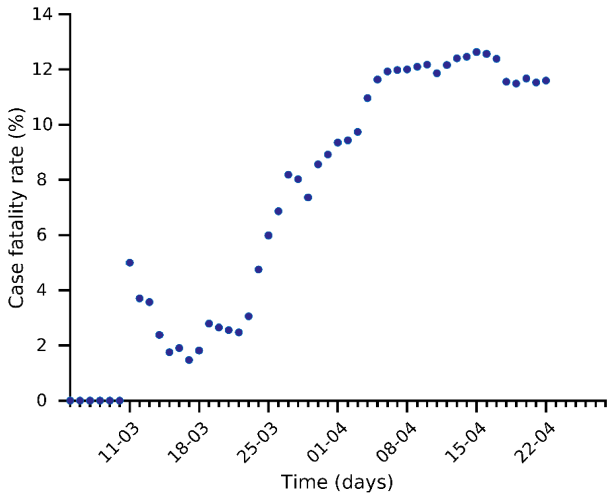




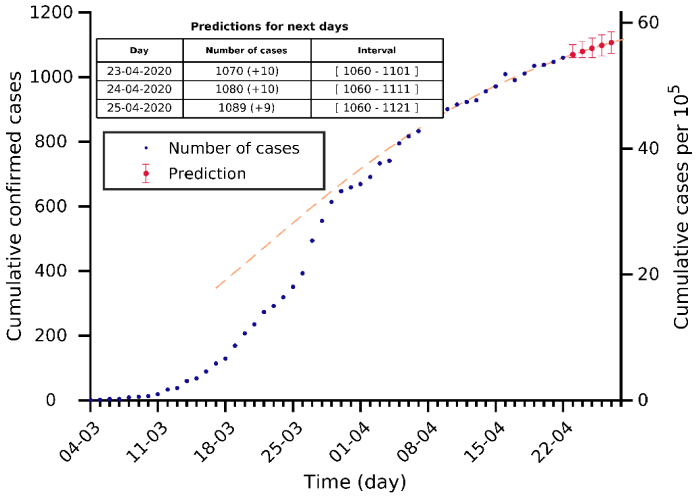


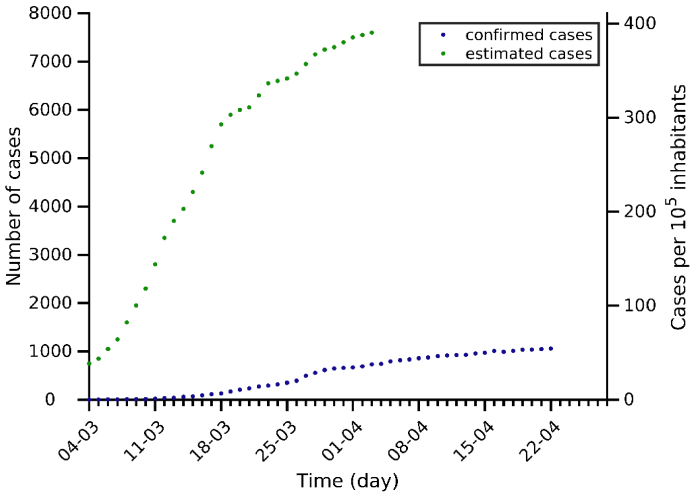


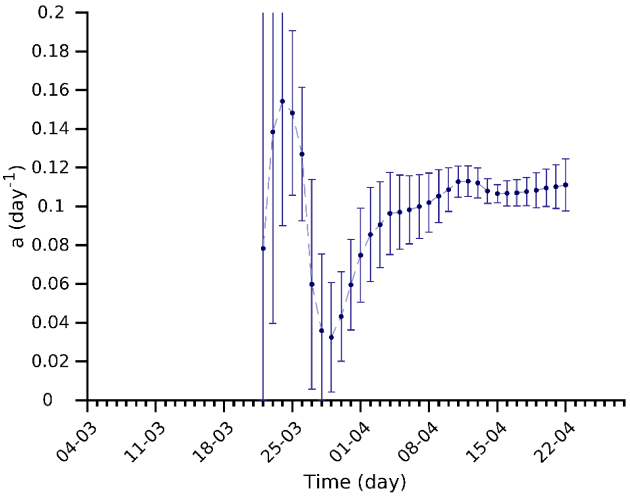


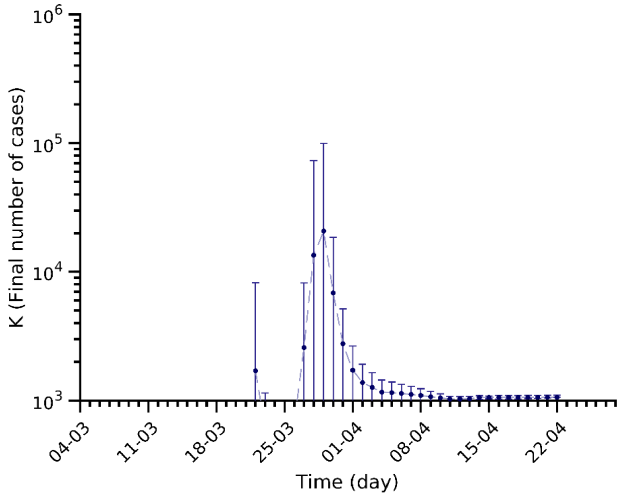


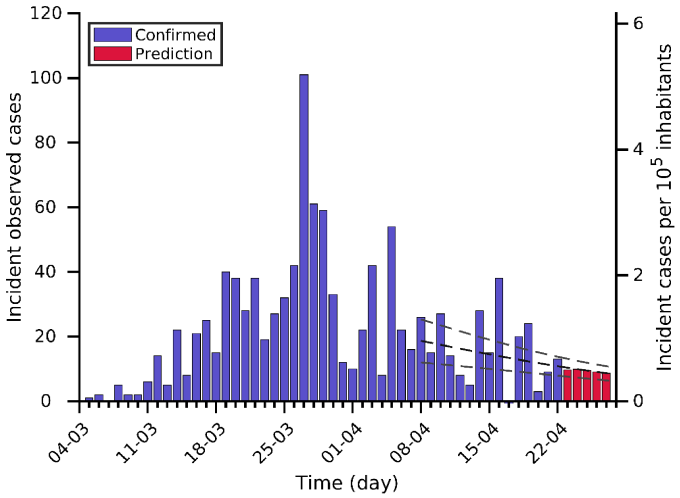
Calabria 22-04-2020. Population: 1.9M. Current cumulated incidence: 54/10^5

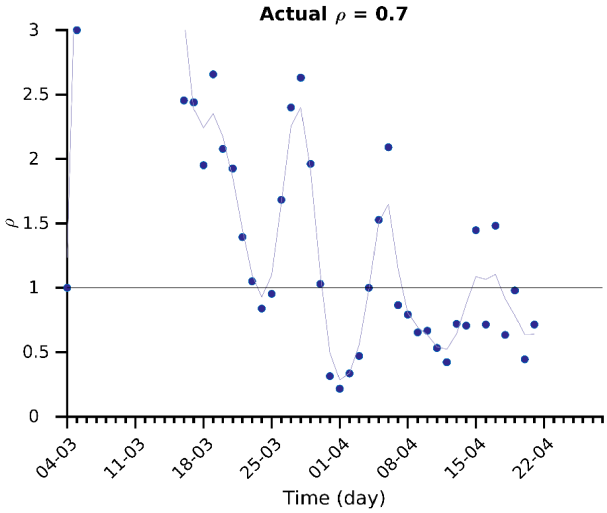


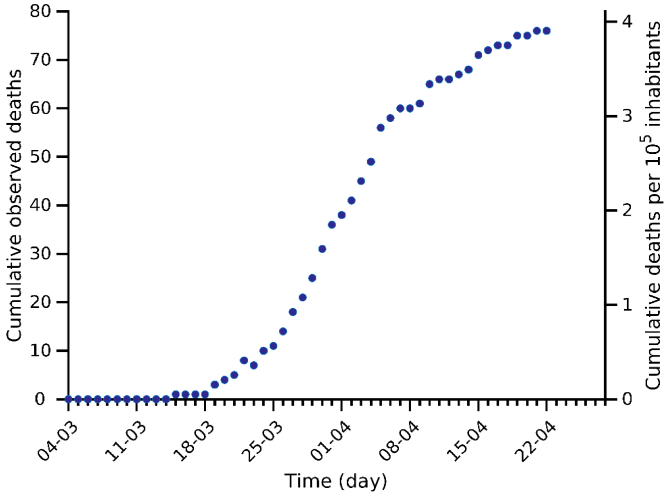


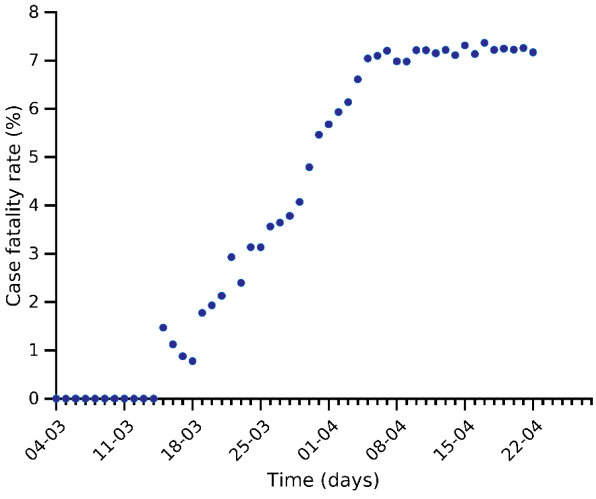




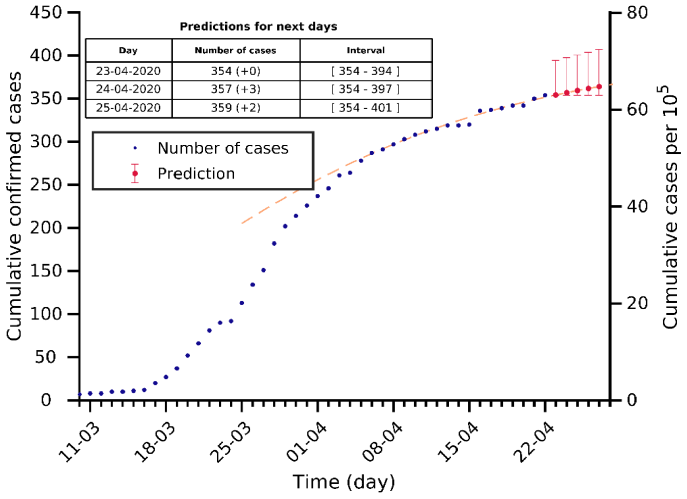


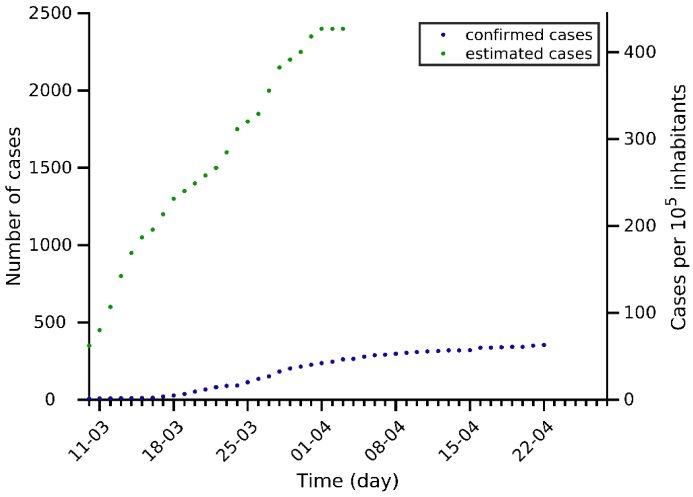


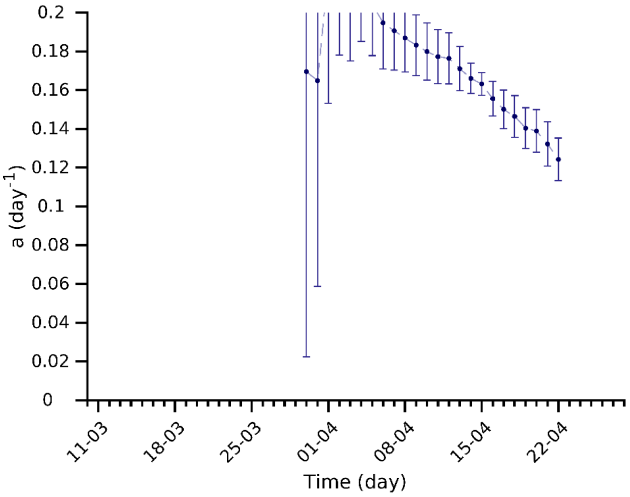


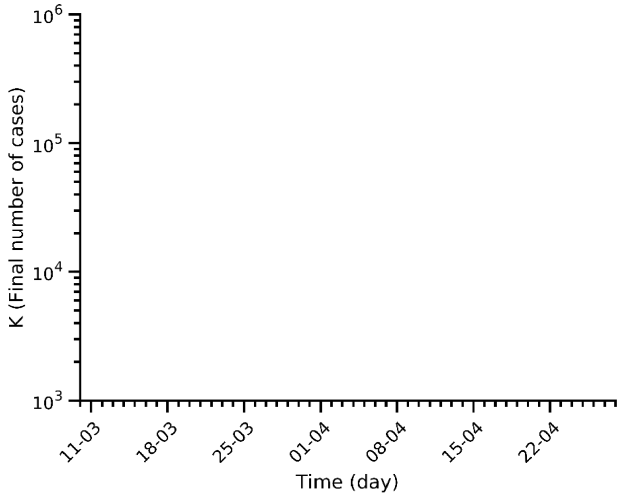


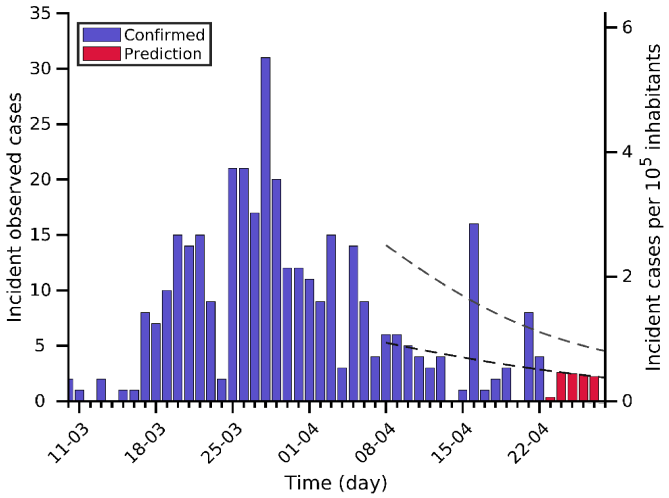
Basilicata 22-04-2020. Population: 0.6M. Current cumulated incidence: 63/10^5

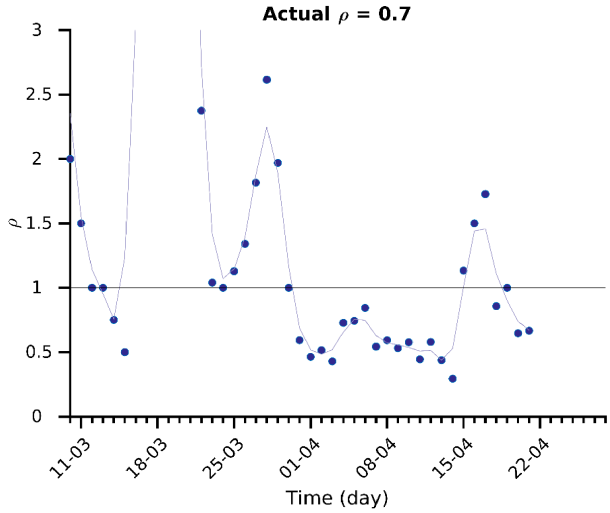


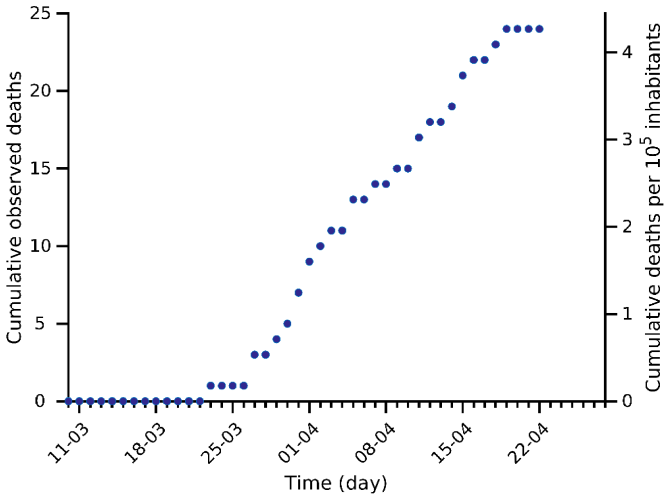


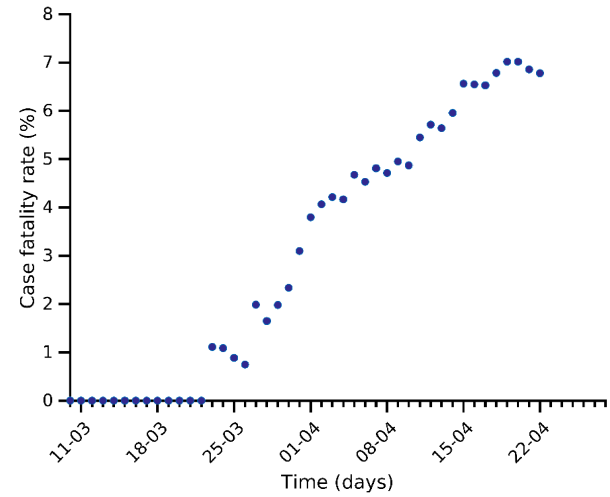




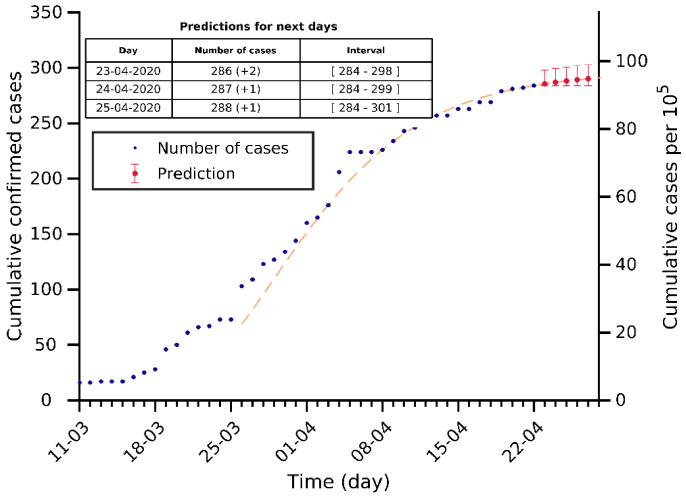


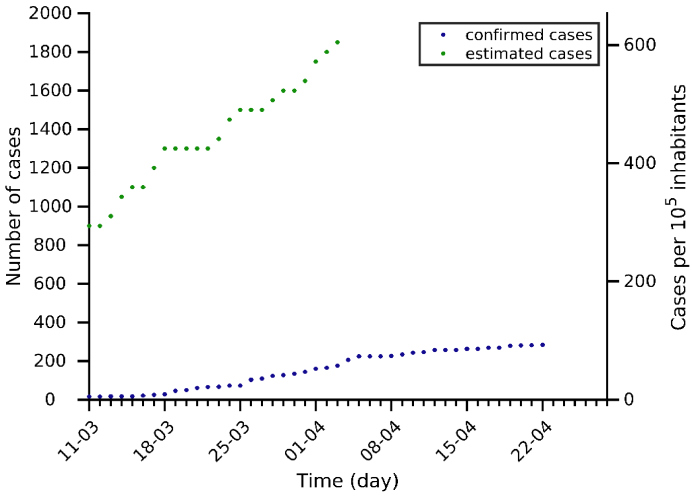


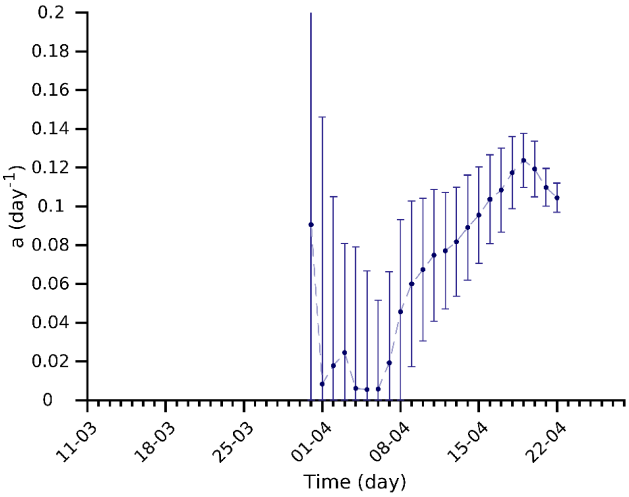


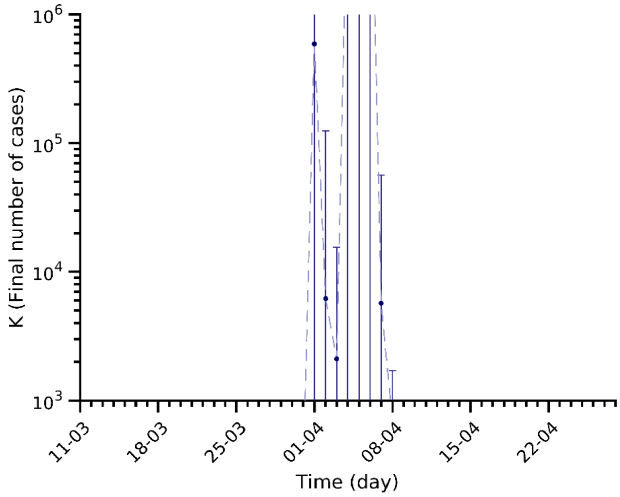


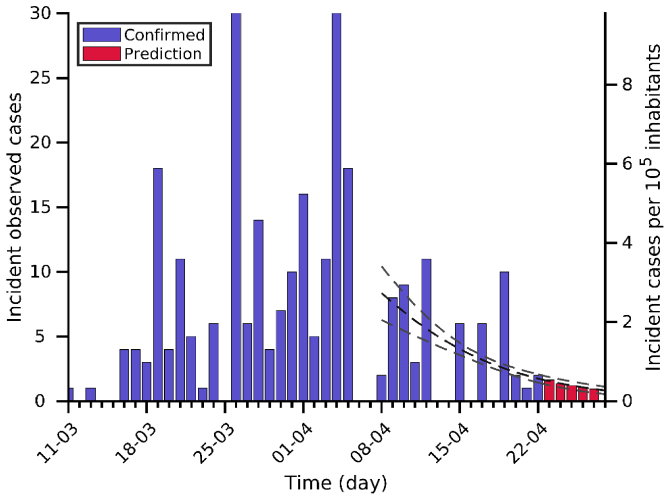
Molise 22-04-2020. Population: 0.3M. Current cumulated incidence: 93/10⁵

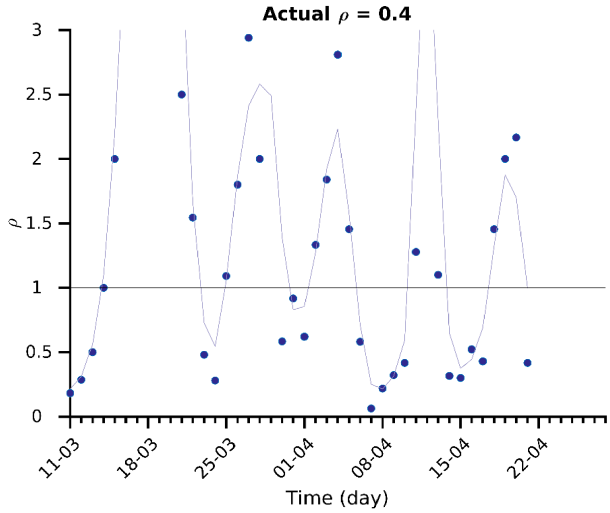


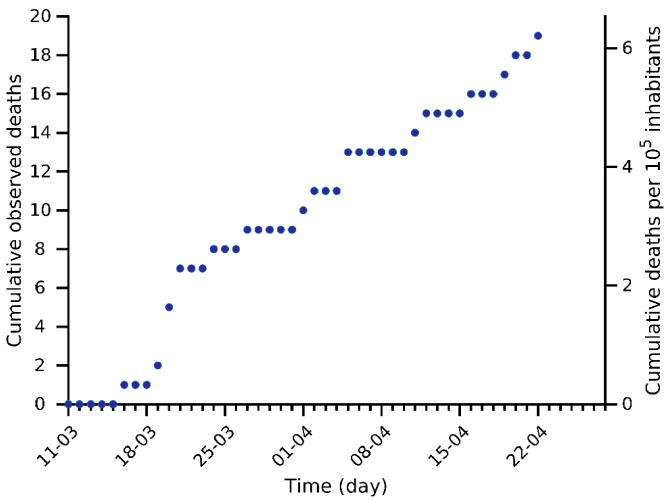


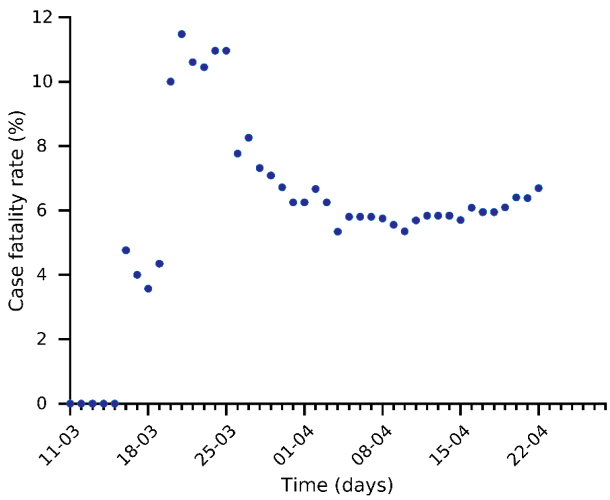












Methods

Methods

(1) Data source

Data are daily obtained from World Health Organization (WHO) surveillance reports[2], from European Centre for Disease Prevention and Control (ECDC)[3] and from Ministerio de Sanidad[4]. These reports are converted into text files that can be processed for subsequent analysis. Daily data comprise, among others: total confirmed cases, total confirmed new cases, total deaths, total new deaths. It must be considered that the report is always providing data from previous day. In the document we use the date at which the datapoint is assumed to belong, i.e., report from 15/03/2020 is giving data from 14/03/2020, the latter being used in the subsequent analysis.

(2) Data processing and plotting

Data are initially processed with Matlab in order to update timeseries, i.e., last datapoints are added to historical sequences. These timeseries are plotted for EU individual countries and for the UE as a whole:

- ✓ Number of cumulated confirmed cases, in blue dots
- ✓ Number of reported new cases
- ✓ Number of cumulated deaths

Then, two indicators are calculated and plotted, too:

- ✓ Number of cumulated deaths divided by the number of cumulated confirmed cases, and reported as a percentage; it is an indirect indicator of the diagnostic level.
- ✓ ρ: this variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. It is evaluated as follows for the day before last report (*t-1*):

$$\rho(t-1) = \frac{N_{new}(t) + N_{new}(t-1) + N_{new}(t-2)}{N_{new}(t-5) + N_{new}(t-6) + N_{new}(t-7)}$$

where $N_{new}(t)$ is the number of new confirmed cases at day t.

(3) Classification of countries according to their status in the epidemic cycle

The evolution of confirmed cases shows a biphasic behaviour:

(I) an initial period where most of the cases are imported;
(II) a subsequent period where most of new cases occur because of local transmission.

Once in the stage II, mathematical models can be used to track evolutions and predict tendencies. Focusing on countries that are on stage II, we classify them in three groups:

- Group A: countries that have reported more than 100 cumulated cases for 10 consecutive days or more;
- Group B: countries that have reported more than 100 cumulated cases for 7 to 9 consecutive days;
- Group C: countries that have reported more than 100 cumulated cases for 4 to 6 days.

[2] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
[3] https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases
[4] https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm
https://github.com/datadista/datasets/tree/master/COVID%2019

(4) Fitting a mathematical model to data

Previous studies have shown that Gompertz model[5] correctly describes the Covid-19 epidemic in all analysed countries. It is an empirical model that starts with an exponential growth but that gradually decreases its specific growth rate. Therefore, it is adequate for describing an epidemic that is characterized by an initial exponential growth but a progressive decrease in spreading velocity provided that appropriate control measures are applied.

Gompertz model is described by the equation:

$$N(t) = K\, e^{-ln\left(\frac{K}{N_0}\right)\cdot e^{-a\cdot(t-t_0)}}$$

where *N(t)* is the cumulated number of confirmed cases at *t* (in days), and N_0 is the number of cumulated cases the day at day t_0. The model has two parameters:

- ✓ *a* is the velocity at which specific spreading rate is slowing down;
- ✓ *K* is the expected final number of cumulated cases at the end of the epidemic.

This model is fitted to reported cumulated cases of the UE and of countries in stage II that accomplish two criteria: 4 or more consecutive days with more than 100 cumulated cases, and at least one datapoint over 200 cases. Day t_0 is chosen as that one at which *N(t)* overpasses 100 cases. If more than 15 datapoints that accomplish the stated criteria are available, only the last 15 points are used. The fitting is done using Matlab's Curve Fitting package with Nonlinear Least Squares method, which also provides confidence intervals of fitted parameters (*a* and *K*) and the R^2 of the fitting. At the initial stages the dynamics is exponential and *K* cannot be correctly evaluated. In fact, at this stage the most relevant parameter is *a*. Fitted curves are incorporated to plots of cumulative reported cases with a dashed line. Once a new fitting is done, two plots are added to the country report:

- ✓ Evolution of fitted *a* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out;
- ✓ Evolution of fitted *K* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out; if lower error bar indicates a value that is lower than current number of cases, the error bar is truncated.

These plots illustrate the increase in fittings' confidence, as fitted values progressively stabilize around a certain value and error bars get smaller when the number of datapoints increases. In fact, in the case of countries, they are discarded and set as "Not enough data" if $a>0.2\ day^{-1}$, if $K>10^6$ or if the error in K overpasses 10^6.

It is worth to mention that the simplicity of this model and the lack of previous assumptions about the Covid-19 behaviour make it appropriate for universal use, i.e., it can be fitted to any country independently of its socioeconomic context and control strategy. Then, the model is capable of quantifying the observed dynamics in an objective and standard manner and predicting short-term tendencies.

(5) Using the model for predicting short-term tendencies

The model is finally used for a short-term prediction of the evolution of the cumulated number of cases. The predictions increase their reliability with the number of datapoints used in the fitting. Therefore, we consider three levels of prediction, depending on the country:

[5] Madden LV. Quantification of disease progression. Protection Ecology 1980; **2**: 159-176.

- Group A: prediction of expected cumulated cases for the following 3-5 days[6];
- Group B: prediction of expected cumulated cases for the following 2 days;
- Group C: prediction of expected cumulated cases for the following day.

The confidence interval of predictions is assessed with the Matlab function `predint`, with a 99% confidence level. These predictions are shown in the plots as red dots with corresponding error bars, and also gathered in the attached table. For series longer than 9 timepoints, last 3 points are weighted in the fitting so that changes in tendencies are well captured by the model.

(6) Estimating non-diagnosed cases

Lethality of Covid-19 has been estimated at around 1 % for Republic of Korea and the Diamond Princess cruise. Besides, median duration of viral shedding after Covid-19 onset has been estimated at 18.5 days for non-survivors[7] in a retrospective study in Wuhan. These data allow for an estimation of total number of cases, considering that the number of deaths at certain moment should be about 1 % of total cases 18.5 days before. This is valid for estimating cases of countries at stage II, since in stage I the deaths would be mostly due to the incidence at the country from which they were imported. We establish a threshold of 50 reported cases before starting this estimation.

Reported deaths are passed through a moving average filter of 5 points in order to smooth tendencies. Then, the corresponding number of cases is found assuming the 1 % lethality. Finally, these cases are distributed between 18 and 19 days before each one.

[6] At this moment we are testing predictions at 4 days for countries with more than 100 cumulated cases for 13-15 consecutive days, and 5 days for 16 or more days.

[7] Zhou et al., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The Lancet; March 9, doi: 10.1016/S0140-6736(20)30566-3